A Land Above: Protecting Baja California's Sierra San Pedro Mártir within a Biosphere Reserve

RICHARD A. MINNICH, ERNESTO FRANCO-VIZCAÍNO, JOAQUÍN SOSA-RAMÍREZ, JACK H. BURK, W. JAMES BARRY, MICHAEL G. BARBOUR, and HORACIO DE LA CUEVA-SALCEDO

Resumen: Como reserva de la biosfera, la Sierra de San Pedro Mártir puede traer grandes beneficios para México y la comunidad internacional. La reserva de la biosfera ayudará a conservar una región de aislamiento geográfico y biodiversidad sorprendente, que incluye muchas especies raras y endémicas. La Sierra también puede servir como un ejemplo extraordinario de ecosistemas que funcionan en un régimen de disturbios naturales a escala de paisaje y bajo sistemas de manejo tradicionales en comparación con ecosistemas similares de zonas templadas pero bajo diferentes tipos de manejo. En la Sierra existe una economía ganadera preservada desde el siglo XIX y una pequeña población nativa. Adicionalmente, el hábitat es propicio para un experimento de importancia internacional: la reintroducción del cóndor californiano.

Existen antecedentes históricos de protección de la Sierra: la Reserva Nacional Forestal y del Parque Nacional Sierra de San Pedro Mártir. Hay experiencia científica en ecología terrestre, antropología y otras disciplinas relacionadas, además de la infraestructura de investigación existente en el Observatorio Astronómico Nacional. Esta experiencia científica puede ser utilizada para las funciones de educación y capacitación dentro de la reserva propuesta. Las visitas guiadas al Observatorio, los arroyos de la trucha, el sitio arqueológico de la Misión de San Pedro Mártir, el alpinismo al Picacho del Diablo, la observación de cóndores y otras actividades reforzarían un sentido de conservación en las poblaciones locales hacia los sitios de importancia histórica, arqueológica y biológica dentro de la reserva de la biosfera.

Nuestro grupo multidisciplinario de investigación ha generado una amplia base de datos como resultado de los estudios en climatología, hidrología, ecología, historia de incendios, impactos del pastoreo y arqueología, a partir de la cual pueden surgir investigaciones ulteriores

que ayuden a conciliar el uso actual de los recursos con la conservación biológica. Un plan de manejo para la reserva puede conservar muchos aspectos actuales de la economía y uso del suelo. Así, la transición hacia una reserva de la biosfera se puede llevar a cabo sin menoscabo de las actividades de la población rural.

We propose that the Sierra San Pedro Mártir (SSPM), a spectacular mountain range of great biotic richness and cultural importance located 100 km southeast of Ensenada, Baja California (see figures 1–2), be declared a biosphere reserve under the Man and Biosphere (MAB) programs of Mexico and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). The Sierra is the southern limit of the Californian floristic province, an important center of biodiversity in North America that is currently threatened by accelerating development. The Californian province is characterized by Mediterranean-type vegetation that occurs nowhere else in Mexico (Wiggins 1960, 1980; Rzedowski 1978; Minnich 1987a).

Within the Californian floristic province, the Sierra is unique in that its open and majestic mixed conifer forests and extensive chaparral and coastal sage scrub are still influenced by uncontrolled, periodic fires. Because forests in California (U.S.A.) have experienced fire suppression for almost one hundred years, the SSPM is the only extant scientific control for experimental and comparative studies with which to inform and improve fire management policies, not only in the United States and Mexico, but also in other Mediterranean regions.

The Sierra is home to 15 species of endemic plants, 20 subspecies of endemic birds, and five species and three subspecies of endemic mammals (see tables 1–4). It also hosts the largest single population of mountain sheep (*Ovis canadensis*) in Baja California, as well as an endemic subspecies of rainbow trout (*Oncorhynchus mykiss nelsonii*) adapted to warm water. Finally, the Sierra's precipitous eastern escarpment—site of Mexico's National Astronomical Observatory—has recently been considered for the possible reintroduction of the endangered California condor (*Gymnogyps californianus*).

The region's remoteness has also preserved summer-season (transhumance) grazing of cattle by families rooted to the region's open-range livestock economy, a rural land-use pattern that dates back to the last years of the San Pedro Mártir Dominican mission early in the nineteenth century. The Kiliwa, one of the last native cultures that still prac-

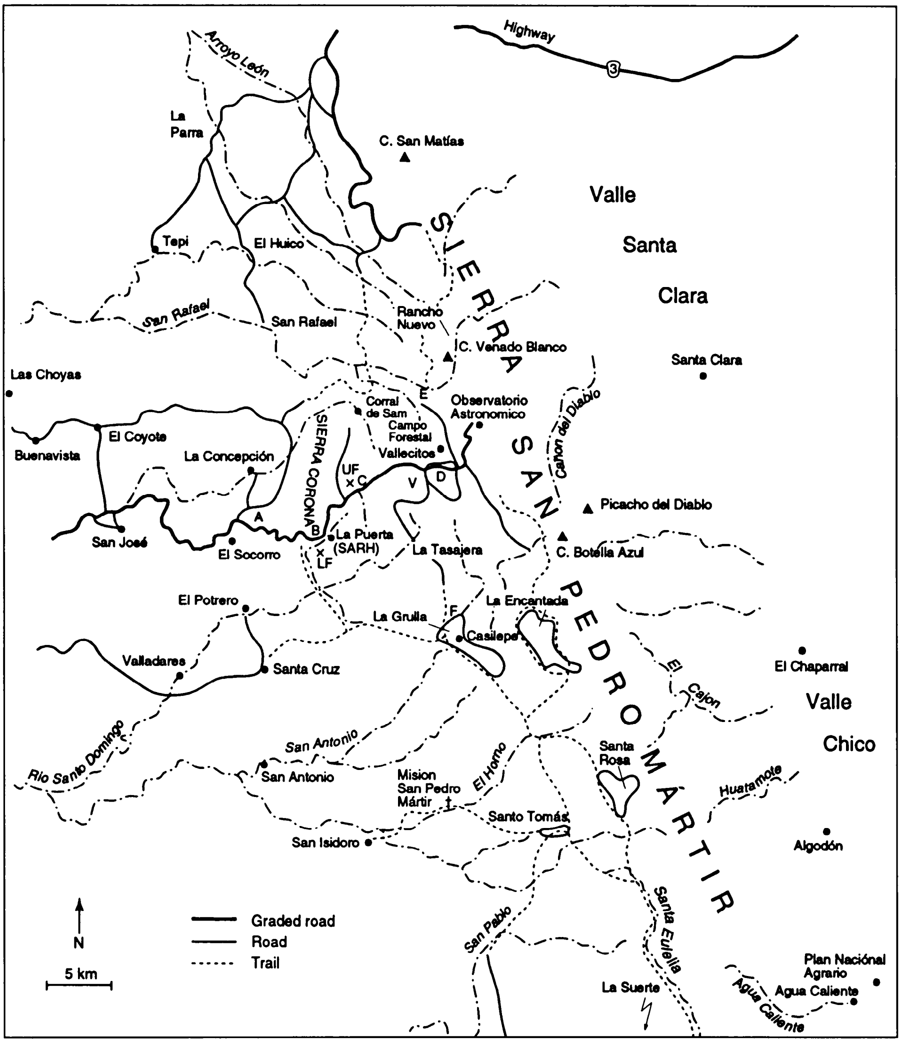


Figure 1. The Sierra San Pedro Mártir, place-names, and study sites. Rain gauge stations: A = W slope, 1,500 m; B = W slope, 2,000 m; C = W plateau, 2,500 m; D = E plateau, 2,400 m; E = N plateau, 2,350 m; F = central plateau, 2,200 m. Lysimeter and exclosure sites: LF = lower forest; UP = upper forest; V = Vallecitos. Tree-ring fire chronology sites: 1 = Sierra Corona;
2 = Corona Arriba; 3 = Los Pinos; 4 = Vallecitos; 5 = La Tasajera; 6 = Blue Bottle Mountain; 7 = N La Grulla; 8 = S La Grulla; 9 = Pyramid Hill;
10 = Cerro Venado Blanco. Solid lines delimit the meadows of La Grulla, La Encantada, Santa Rosa, and Santo Tomás.

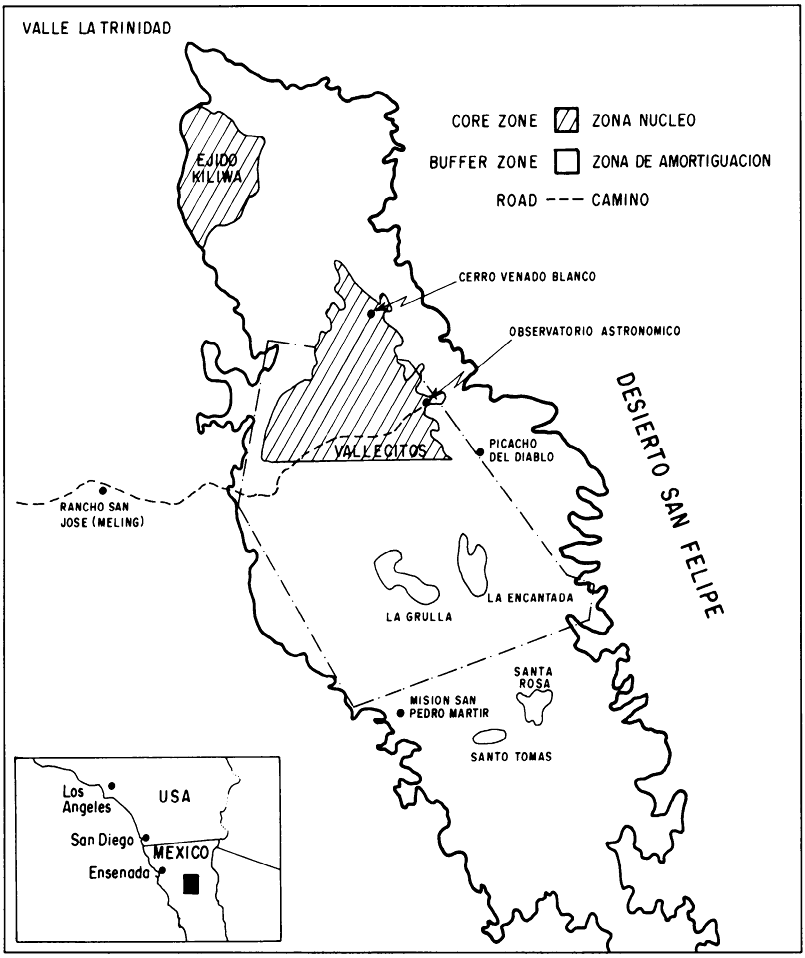


Figure 2. Limits of the San Pedro Mártir National Park (dashes and dots), and proposed limits of the San Pedro Mártir Biosphere Reserve (heavy solid line), with the proposed limits of the two core zones.

tice hunting and gathering in North America, inhabit the Sierra's northern slopes (Meigs 1935, 1939; Hinton and Owen 1957; Owen 1963).

Establishing the San Pedro Mártir Biosphere Reserve would provide a flexible institutional framework to manage the Sierra's biotic, eco-

nomic, and cultural resources; however, this will require formalizing cooperation among the diverse groups with vested interests in the Sierra. We propose two separate core zones for consideration (see figure 2): The main core zone would be located in the mixed conifer forest north of Vallecitos and would include Cerro Venado Blanco and Rancho Nuevo. This core zone would protect the installations of the National Astronomical Observatory and the northwestern portion of Vallecitos meadow. Vallecitos meadow and the forest to the north—among the richest and most diverse mixed conifer forests in the Sierra—are key areas for conservation and research. The livestock industry would not be severely affected because the primary grazing resources are the more verdant meadows to the south. Also, Vallecitos has good access for maintenance of infrastructure, and this would facilitate recreation, education, and environmental monitoring. The second core zone would comprise the Kiliwa settlements. The Kiliwa are descendants of the Sierra's first inhabitants, and their rich culture, language, and land-use patterns are perilously close to vanishing.

The surrounding buffer zones would include lands used for seasonal livestock grazing, the habitat of the bighorn sheep, the streams containing the rainbow trout, and the Mission San Pedro Mártir de Verona. Ejido lands (a communal land-tenure system created by land reform in Mexico) immediately surrounding the Sierra could be included as part of the outer transition zone to encourage economic activities by the local residents, integrated with long-term conservation goals.

A key concept of the "Mexican modality" in biosphere reserves is the integration of conservation and rural development so that researchers and protected-area managers take into account the concerns and aspirations of local populations. In the Sierra, the rural population relies on cattle grazing for its basic economy, and many of the inhabitants have developed an intimate and time-honored understanding of the natural environment. A mutual understanding of the region's social, economic, political, and ecological problems needs to be acquired by scientists, resource users, and managers.

However, sustainable use of the Sierra's natural resources will require continued research on the impacts of grazing in relation to vegetation, wildland fire, and management of wildlife. The reintroduction of the California condor to the Sierra might serve as a rallying point for obtaining regional, national, and international support for the reserve.

HISTORY OF THE SAN PEDRO MÁRTIR BIOSPHERE RESERVE PROPOSAL

In anticipation of the potential for exploitation at the global and regional levels of formerly inaccessible regions rich in biodiversity, UNESCO developed the MAB program, a worldwide system of biosphere reserves with various aims, among them sustainable use of natural resources, recuperation of species, and protection of habitat. An important aspect of the UNESCO MAB program is to reconcile conservation and development by fostering scientific research. The Mexican model of biosphere reserves (*la modalidad mexicana*) augments the original concept of conserving biodiversity, ecological research, education, and training by addressing regional socioeconomic problems through the participation of local populations and institutions in the shared work of conservation (Halffter 1981; Gómez-Pompa and Kaus 1992). As a result of the publication of the General Law on Ecological Equilibrium and Protection of the Environment of 1988, presidential decrees have established more biosphere reserves (Reyes-Castillo 1991).

In 1986, the Directorate of Biosphere Reserves of the U.S. MAB program convened a binational panel to identify, evaluate, and select sites in the Californian Biogeographical Province for nomination as biosphere reserves to the UNESCO MAB Program (Barry 1991). Among the sites selected in California (U.S.A.) were Cuyamaca State Park, Palomar Mountain State Park, and Mount San Jacinto State Park, and in Baja California (Mexico) the Parque Nacional San Pedro Mártir and Parque Nacional Constitución de 1857 (in the Sierra Juárez). Later, a resolution recommending increased dialogue and cooperative efforts toward a transnational biosphere reserve in the Peninsular Range of the Californias was passed by the Environmental Committee of the Commission of the Californias (Barry 1991).

Baja California's forests have been protected areas since the Mexican government established a forestry reserve in 1923 that includes SSPM, the Sierra Juárez, and Mesa del Pinal. The Sierra was further protected by the establishment in 1947 of the San Pedro Mártir National Park (63,000 ha), the first on the peninsula (Gómez-Pompa and Dirzo 1994). The national park, which to date has only primitive infrastructure and little effective management or surveillance, is moderately used by campers and climbers from such nearby urban centers as Ensenada, Tijuana, and Mexicali, as well as San Diego and Los Angeles.

The importance of the SSPM to scientific research is indicated by the extensive bibliography available on the region, which is cited in this work and in the general bibliography that follows. Quantitative studies on land use and vegetation dynamics, as well as the archaeology and cultural history of the Sierra San Pedro Mártir and Mount San Jacinto core areas, were carried out by our binational research team during 1989–92 with funding received from the U.S. MAB and the National Science Foundation (NSF), the Mexican National Council on Science and Technology (CONACyT), and the University of California Institute for Mexico and the United States (UC MEXUS). As part of the U.S. MAB grant, we held a symposium on "The Potential of the Peninsular Range of the Californias as a Biosphere Reserve" in Ensenada, Baja California, in March 1991, to promote discussion on the potential of the five Peninsular Range parks to become a cluster biosphere reserve (Franco-Vizcaíno and Sosa-Ramírez 1991).

The discussion that evolved out of that first conference indicated that an initiative to establish a transnational biosphere reserve would be premature given the current complications of binational protected-area management and the changing political climate. Nevertheless, the opinion of the conference participants was that the ecological and social characteristics of the Sierra were of particular importance for conservation efforts, and a more viable initial strategy would be to nominate the Sierra as a biosphere reserve based on its own merit, rather than as part of a larger system.

To foster community input and participation, we invited leaders of the ejidos that have traditionally grazed cattle in the Sierra and elders of the Kiliwa community, as well as owners of guest ranches, representatives of governmental and non-governmental organizations, and the academic community to a second conference, "Strategies for Conservation of the Sierra San Pedro Mártir" held in Ensenada in December 1995 (Franco-Vizcaíno, Cueva, and Montes 1996). During this second conference, the cattle ranchers declared that because of the unprofitability of grazing, the Ejido Bramadero was seeking ways to diversify its use of the Sierra's natural resources (Meling-Pompa, 1996) and was seeking a permit to log the forested areas of the ejido. Subsequently, the ejido obtained from the Mexican federal government a permit to remove dead and diseased trees in the ejido lands. Petitions for logging permits by other ejidos and private landowners are currently under review.

Thus, regional demographic and economic development on both sides of the international boundary are accelerating demand for the

Sierra's open spaces and natural resources. There will likely never be a more favorable opportunity to establish a biosphere reserve to protect the area's natural resources and pastoral land-use system, as well as the observatory's scientific infrastructure. Establishing the biosphere reserve will require the formalized cooperation of the diverse groups with vested interests in the Sierra. A binational non-governmental organization, Bosques de las Californias Asociación Civil has been organized in Ensenada to represent some of these interests, with a view toward promoting the establishment of the San Pedro Mártir Biosphere Reserve.

In October 1996, 25 high-priority natural protected areas in Mexico were decentralized, with the SSPM being the only national park among them. Administrative responsibility for the Sierra now rests with the Oficina del Parque Nacional, an agency that is independent of federal, state, and municipal governments. Its decision making is supported by the Ministry of the Environment's National Institute of Ecology, the Institute of Astronomy, the Institute of Ecology of the National Autonomous University of Mexico (UNAM), the Faculty of Sciences of the Autonomous University of Baja California (UABC), and the Center for Scientific Research and Higher Education of Ensenada (CICESE). The Oficina is currently developing a management plan for the national park that is more in line with the MAB Mexico program than the traditional "hands off" approach to protected-area management. This emphasis may greatly enhance the possibility of turning the SSPM into a biosphere reserve.

The Oficina has developed an initial plan that involves several uses of the land and its resources, and which includes ecotourism and conservation of the rainbow trout. As a more detailed management plan is elaborated by the Oficina and its technical advisory committee, many of the ideas on potential land use will be assessed and those compatible with sustainable use will be encouraged.

CHARACTERISTICS OF THE REGION

The Sierra San Pedro Mártir is a spectacular fault-bound range in the Peninsular Range geomorphic province (Gastil, Phillips, and Allison 1975; O'Conner and Chase 1989). It extends southeastward from

Valle Trinidad to 50 km west of San Felipe (see figure 1). The range has three distinct terrain sectors: eastern escarpment, crest, and western flank. The eastern escarpment is greatly dissected with deep canyons and intervening ridges. Relief is nearly vertical from the spine of the range (2,500 m) to the floor of the Sonoran Desert (altitude 500 m; see plate 1). The crest of the Sierra is a broad plateau consisting of shallow alluvium-filled basins and extensive meadows with surface elevations decreasing in three steps from Vallecitos in the north at 2,400 m, to La Grulla and La Encantada at 2,200 m, to Arroyo Santa Eulalia in the south at 1,600 m. Higher ridges and local summits divide the plateau from the eastern escarpment, with elevations ranging up to 3,100 m at Picacho del Diablo. The western flank is a steep, smooth, undissected fault escarpment with locally sharp relief of 300 to 600 m. Farther west are rugged foothills and mesas, rimmed by the extensive plain of Valle San Telmo and by marine terraces along the coast.

Climate

The Sierra San Pedro Mártir lies at the southern margin of the North American Mediterranean climatic zone (Markham 1972; Reyes-Coca, Miranda-Reyes, and García-López 1990). Winter cyclones bring frontal rains, with snow at higher elevations, between November and April. Summer is mostly warm and dry, but afternoon thundershowers, which result from the North American monsoon, occur from July to September. Average winter daytime temperatures are mild, ranging from 10°C in coastal and desert valleys to 0°C near the observatory. In summer, mean monthly daytime temperatures range from 25°C on the lower coastal slope to 15°C at the observatory, and rise to 30°C in the Sonoran Desert (Alvarez 1981; Reyes-Coca, Miranda-Reyes, and García-López 1990).

Although weather stations exist both at National Park Headquarters at La Puerta and at the observatory, data have not been consistently taken, and so long-term precipitation data are lacking for the Sierra. Rancho Santa Cruz (altitude 960 m), the only weather station near the western slope, averages 265 mm annually, with 90 percent of precipitation occurring in winter. In the Santa Clara basin east of the Sierra, the average precipitation at several ranches ranges from 160 to 180 mm per year with 70 percent of precipitation occurring in summer.

In June 1990, we erected a modest network of bulk precipitation gauges along east-west and north-south axes across the Sierra (see figure 3). We obtained precipitation data biweekly in summer, and monthly to bimonthly in winter. The capacity of the gauges was greatly exceeded during the extreme precipitation events of January 1993, and the network was subsequently removed. Nevertheless, bulk precipitation data show that summer afternoon thundershowers produce 100 to 200 mm (4 to 8 in.) on the plateau. Summer precipitation then decreases rapidly westward to less than 20 mm (0.8 in.) at Rancho Santa Cruz.

During winter, orographic lift of frontal air masses from the Pacific Ocean results in steadily increasing precipitation from 260 mm (10 in.) at Rancho Santa Cruz to 450 to 550 cm (18 to 22 in.) on the western and central plateau. Amounts decrease to 400 mm (16 in.) on the eastern and northern plateau due to rain shadows extending from the western rim. Total winter precipitation varied from 260 to 280 mm during the drought year of 1989–90 to 550 to 650 mm during the wet years of 1990–91 and 1991–92. The average annual precipitation is estimated to increase from 270 cm (12 in.) at the western base of the Sierra to 600 mm (24 in.) on the western plateau and 500 mm (20 in.) on the northern and eastern plateaus.

Storm freezing levels, revealed by radiosonde data, show that the proportion of winter precipitation occurring as snow increases from 15 percent at 1,700 m to 80 percent at 2,600 m (Minnich 1986). This was confirmed by snowpack measurements taken during 1991 and 1992 (see figure 4), when snow depths varied from 300 to 900 mm and snowpack densities were 30 to 40 percent between December and March. These results are similar to those reported for the Sierra Nevada of California (Miller 1955). High snowpack densities (heavy snow) reflect warm ambient temperatures (ca. 0°C) during winter storms. The snowpack's water content equivalent varied from 70 to 700 mm. Snow had entirely melted by April or early May.

Vegetation

The Sierra's vegetation, interpreted from aerial photographs (after Minnich 1987a, 1988), shows the broad altitudinal zonation common to the Peninsular Ranges of southern California (Barbour 1988). Local patterning is modified by slope, aspect, and substrate. Chaparral on the

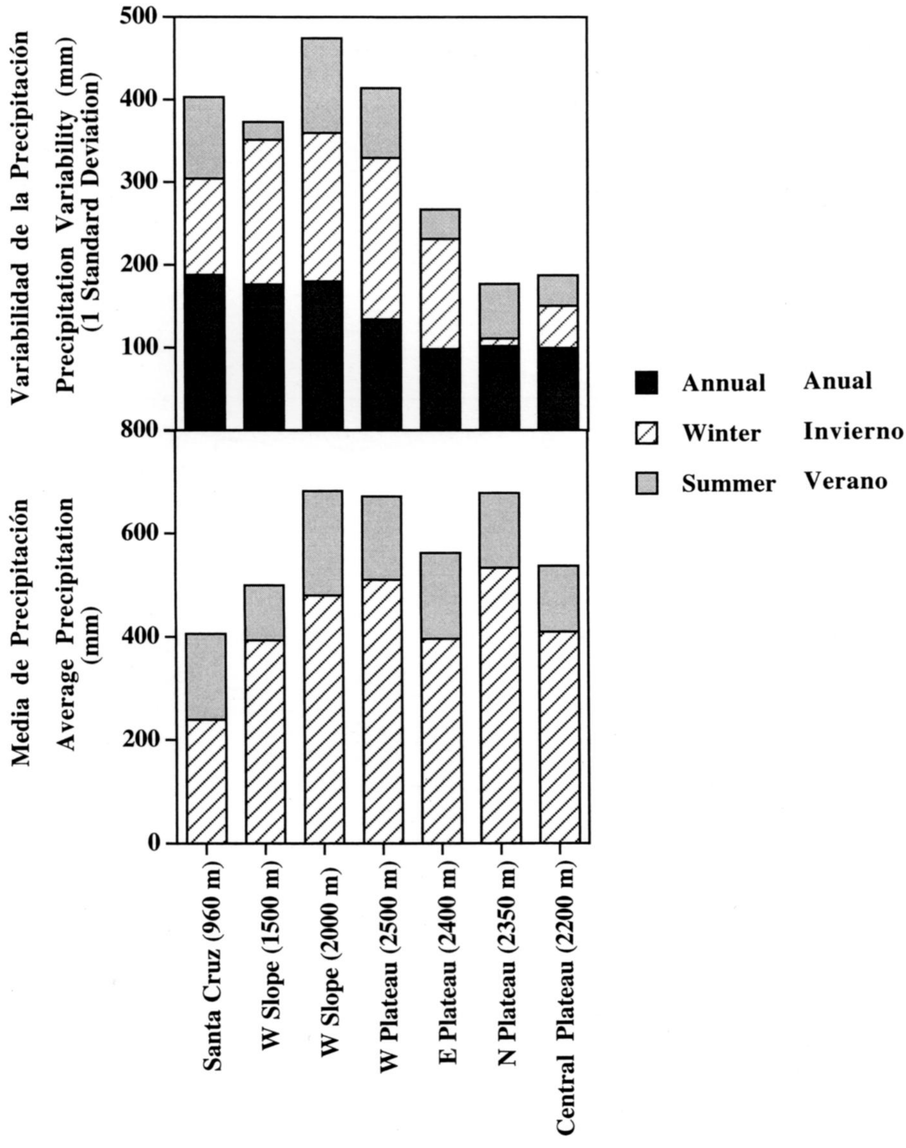


Figure 3. Mean summer, winter, and annual precipitation and its variability.

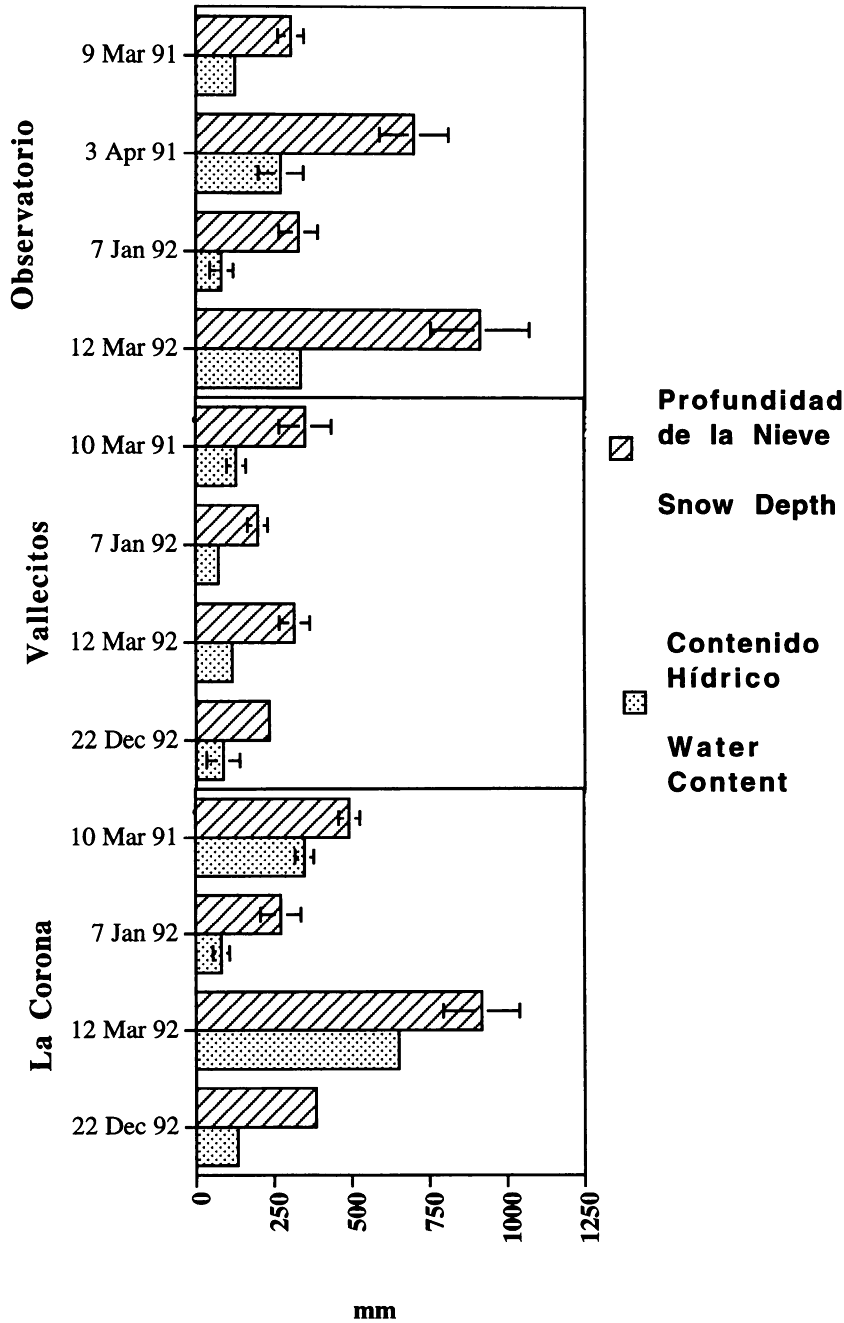


Figure 4. Snowpack depths and equivalent water content.

lower western slope is replaced by mixed conifer forest on the summit plateau. This is followed on the eastern escarpment by pinyon forest at the higher elevations and Sonoran Desert scrub below 1,200 m. Common species are listed in table 1, habitats of rare and endangered species are given in table 4, and the spatial extent of vegetation types is given in table 5.

The Sierra's western flank below 1,800 m is mostly covered by chamise chaparral, which consists of contiguous, single-layered stands of interwoven, evergreen sclerophyllous shrubs dominated by chamise (*Adenostoma fasciculatum*). Other common species are *Ceanothus greggii* and *Rhus ovata*. Minor shrubs and succulents include *Arctostaphylos glauca, Ceanothus leucodermis, Nolina palmeri, Quercus dumosa,* and *Yucca schidigera*. Red shank (*Adenostoma sparsifolium*) chaparral is widespread in areas of granitic substrate.

In the semiarid basins near the base of the western escarpment, chamise grows extensively in open stands with *Juniperus californica* and desert shrubs including Mormon tea (*Ephedra nevadensis*), jojoba (*Simmondsia chinensis*), and *Yucca schidigera*. Above 1,800 m, chamise chaparral gives way to peninsula manzanita (*Arctostaphylos peninsularis*) chaparral, which extends to as high as 2,200 to 2,400 m on steep southern exposures. Chaparral associations grow mostly on steep slopes with infertile, coarse-textured soils. Stands are fragmented into a patch mosaic of different age classes resulting from numerous burns.

In the chaparral zone, tree cover consists of hardwood forests restricted to streams, canyon floors, and margins of basins. Extensive riparian forests of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.) follow the primary trunk streams of the western escarpment. Western sycamore (*Platanus racemosa*) occurs in small stands in the southwestern corner of the Sierra. Coast live oak (*Quercus agrifolia*) grows near arroyos and along fault seeps at the base of the western escarpment between 1,000 and 1,800 m. In the lower west slope chaparral zone are short forests of the four-needle (Parry) pinyon (*P. quadrifolia.)* This tree occurs in a highly fragmented patchwork of thousands of small stands. Two small colonies of Coulter pine (*Pinus coulteri*) are found near the northern and southern extremities of the range. This tree, which is noted for its enormous and partially serotinous cones, grows in dense *Arctostaphylos peninsularis* chaparral.

The semiarid eastern escarpment between 1,500 and 2,700 m is covered by more extensive short forests of *Pinus quadrifolia* (see plate 2).

Below 1,500 m, *P. quadrifolia* is replaced by single-leaf pinyon, *P. monophylla*. Common shrubs in eastside pinyon forests include *Arctostaphylos peninsularis, Cercocarpus betuloides, Fremontodendron californicum, Garrya grisea, Nolina parryi, Quercus chrysolepis, Q. dumosa, Q. peninsularis, Rhus ovata, R. aromatica* (*trilobata*), and leaf-succulents such as *Agave deserti* and *Yucca schidigera* (Chambers 1955; Wiggins 1944).

The eastern escarpment below 1,200 m is covered by Sonoran Desert microphyll woodlands and creosote bush scrub. Creosote bush scrub is characterized by the nearly evergreen shrub *Larrea tridentata* and drought-deciduous subshrubs such as *Ambrosia dumosa* and *Encelia farinosa*. Important shrubs of microphyll woodland include *Cercidium floridum, Olneya tesota,* and *Psorothamnus spinosus.* Both communities contain many stem- and leaf-succulents such as *Agave deserti, A. moranii, Fouquieria splendens, Pachycereus pringlei,* and diverse *Opuntia* spp. On the eastern escarpment of the southern Sierra San Pedro Mártir are numerous populations of blue fan palm (*Brahea armata*), mostly near springs that seep from volcanic cap rock overlying granitic basement (see plate 3). This palm also extends westward to the coastal escarpment as far north as Arroyo San Pablo.

Undulations in the topography of the crestal plateau result in variation in the species composition and distribution of mixed conifer forests. The lower plateaus between 1,500 and 2,100 m are covered by monotypic forests of Jeffrey pine (*Pinus jeffreyi*), with most stands concentrated on basin floors and the margins of meadows. Above 2,100 m, *P. jeffreyi* forest gives way to a belt of floristically richer mixed conifer forests covering hillslopes and basin floors (see plates 4 and 5) in a manner similar to that of California forests. Southern exposures are dominated by *P. jeffreyi* mixed with white fir (*Abies concolor*) and sugar pine (*Pinus lambertiana*). *Abies concolor* is dominant on northern exposures, but *P. lambertiana* is locally dominant on steep slopes and cliffs. The mountain cypress (*Cupressus montana*), a Baja California endemic, is frequently found in forests of *A. concolor* and *P. lambertiana* on the upper eastern escarpment. Lodgepole pine (*Pinus contorta*) is locally abundant in high meadows such as Vallecitos. Incense cedar (*Calocedrus decurrens*) is found along watercourses and some north-facing slopes, mostly on the western rim of the plateau.

Among broadleaf trees, quaking aspen (*Populus tremuloides*) grows at wet sites above 2,400 m. Canyon live oak (*Quercus chrysolepis*) forms

an understory beneath mixed conifer forest on hilly areas of the plateau, as well as on steep north-facing exposures of the surrounding escarpments. Pacific Emory oak (*Q. peninsularis*), a Baja California endemic, grows extensively as understory beneath *P. jeffreyi* forests south of La Grulla. Important shrubs in the understory of mixed conifer forests are *Arctostaphylos patula, A. pringlei, A. pungens, Artemisia tridentata, Ceanothus cordulatus, Salvia pachyphylla,* and *Symphoricarpos parishii.*

The forest belt contains numerous wet meadows that are the focal point of summer cattle grazing. Most meadows are relatively small, but in the central Sierra several meadows (La Grulla, La Encantada, and Santa Rosa) cover areas greater than 500 ha each (see plates 6 and 7). Dominant species include *Juncus* spp. and *Carex* spp., similar to those of meadows in the mountains of California. Other common herbs include *Astragalus gruinus, Berula erecta, Cirsium foliosum, Epilobium adenocaulon, Oenothera californica,* and *Ranunculus cymbalaria.* Drier or overgrazed meadows are covered by herbaceous perennials in such genera as *Achillea, Aster, Muhlenbergia,* and *Potentilla.*

The Sierra San Pedro Mártir is the southernmost outpost of Mediterranean vegetation of the Californian floristic province. Hence, nearly all tree species, many of which range as far north as the Cascade Mountains of Oregon and northern California, have their southern limits in the range (Minnich 1987a). *Brahea armata, Pinus monophylla, Populus fremontii,* and *Quercus peninsularis* extend farther south into the mountains of central and southern Baja California. *Abies concolor* and *P. tremuloides* occur in the mountains of the Mexican Altiplano. Most chaparral species also have their southern limits in the Sierra (Moran 1977b; Wiggins 1980).

Surface Hydrology, Soil Classification, and Fertility

Water budgets were estimated at three sites representative of the common plant communities in the Sierra (Escoto-Rodríguez 1994): lower forest (La Puerta, 1,980 m), upper forest (La Corona, 2,470 m), and wet meadow (Vallecitos, 2,380 m) from October 1989 to October 1992, a period of transition from dry to wet winters (La Niña–El Niño). At the two forest sites, precipitation averaged 501 ± 17 mm in winter and 191 ± 100 mm in summer. Winter evapotranspiration (ET) was about 40 percent of winter precipitation, while summer ET was

about 125 percent of summer precipitation. Precipitation at the meadow site in Vallecitos averaged 386 ± 141 mm in winter, and 161 ± 22 mm in summer. But while winter ET was about 40 percent of winter precipitation, summer ET was about 200 percent of summer precipitation. These results indicate that forest and meadow vegetation use all the rain that falls during summer, and also require additional moisture stored in the soils during the previous winter. Overall, annual ET in the forest sites was 59 ± 21 percent of annual precipitation, but it was 87 ± 12 percent at Vallecitos.

At all three sites, some 60 percent of winter precipitation goes to runoff or deep drainage. Most of this moisture is released to streamflow lower in the watershed. The rest is stored in the soil profile and mobilized during summer. The amount carried over from winter to summer averages 40 mm at the forest sites, and about 300 mm in the wet meadows. Thus, shallow water tables must supply moisture to the vegetation in the meadows, particularly during wet years. After a wet winter (1993), the depth to the water table in late summer varied from 50 to 150 cm in the meadows at Vallecitos (Franco-Vizcaíno and Graham, unpublished data).

An important difference between the upper and lower forest sites is that the snowpack turns icy and the soil freezes at higher elevations. In the lower forest, snow melts quickly and meltwater percolates through the soil to produce significant deep drainage. In the upper forest, the snowpack remains for two to three months at a time, and meltwater apparently runs off over the frozen ground but beneath the snowpack. Thus, less water enters the soil profile during winter at the upper forest site, and there is consequently less deep drainage and less water stored in the soils than in the lower forest.

Soils at the three study sites (as well as those of the meadows and much of the Sierra's forest) are derived from granites. They are dark gray to dark gray brown sandy loams to loamy sands. Excavation revealed that soil profiles at the forest sites are moderately deep and well drained, and show little profile development (typic xeropsamments). In the meadow, soils are deep (>150 cm), and appear to be influenced by a strong moisture gradient from the wet meadows to the slightly higher and drier meadow fringes and forests. The meadow soil, a loamy sand, shows moderate profile development and mottling (aeric haplaquepts). This mottling is consistent with an annual cycle of anaerobic conditions during winter and spring when soils are saturated, followed by drying

and aerobic conditions during summer and fall. Schist is the only other major soil parent material in the Sierra. Examination of a soil that developed on schist at a sloping forested site revealed a moderately deep (50 cm), dark brown, well-drained, sandy loam having moderate profile development (typic xerochrepts).

Analysis of soil samples revealed that SSPM soils that are derived from granitoid rocks are moderately acid, non-saline, and infertile (Franco-Vizcaíno, Sosa-Ramírez, and Graham, unpublished data). Concentrations of nitrogen, phosphorus, potassium, and magnesium in the soil solution were critically low, and lower than the minima reported for agricultural soils in California (Franco-Vizcaíno et al 1992).

Fire History

Recurrent fire is the most significant form of natural disturbance in northwestern Baja California (plate 8). This is due to the region's Mediterranean climate, in which winter precipitation is followed by dry summers. Plant cover supported by winter precipitation is desiccated by summer drought, a condition that accentuates fire hazard. The fire-perimeter history (burns greater than 5 ha) was reconstructed synoptically by using a rollfilm stereoscope to delimit burn scars on ten repeat aerial photographic coverages of SSPM taken between 1942 and 1993. It was possible to distinguish scars of fires that occurred as early as about 1925. Fire distributions and patch turnover were followed, and disturbance was distinguished from natural vegetation gradients by using a zoom transfer scope (ZTS) to match specific sites in the time series of repeat aerial photographs. The ZTS allows two scenes to be superimposed exactly to scale by recognizing the unique nearest-neighbor configurations of trees and shrubs within a stand, as well as from surrounding fixed features such as rock outcrops and watercourses. Fire-perimeter maps of SSPM show that most chaparral and forests on the western slope and plateau have burned at least once since 1925. Between 1925 and 1991 there were 865 fires that burned a total of 143,300 ha; of these 56,800 ha were in mixed conifer forest and 75,200 ha in chaparral. A majority of burns (436) were smaller than 16 ha, while only 41 burns exceeded 800 ha and only two burns exceeded 6,400 ha. While small fires of less than 16 ha collectively accounted for 2,511 ha or 1.6 percent of the total burned area, size classes that accounted for the largest burned areas were 800 to 1600 ha (23,718 ha) and 3,200 to 6,400 ha (35,241 ha; see figure 5).

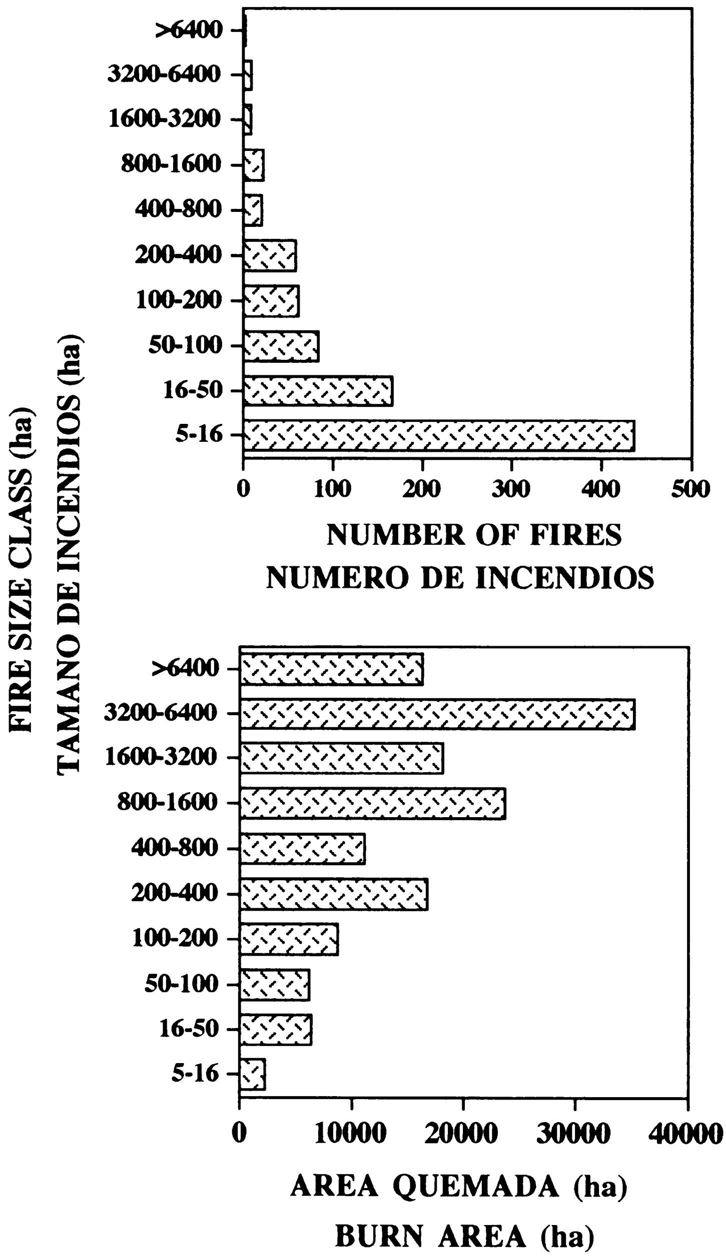


Figure 5. Number of fires and area burned in the sierra during the period 1925–1991, as calculated from maps generated by the geographical information system.

The average fire-rotation period, i.e., the time required to burn an area equivalent to the total area of a vegetation type (Johnson and Gutsell 1994) is estimated to be 50 to 55 years. Accordingly, both forest and chaparral communities have burned about 1.2 times during the 66-year period between 1925 and 1991. Fire-rotation periods in pinyon forest on the semiarid eastern escarpment are estimated to be 100 to 200 years or longer.

Fire control in SSPM has been largely ineffective, and the occurrence of burns along cattle-drive routes suggests that deliberate burning is still practiced. The SSPM was roadless until the construction of the graded road to the National Observatory in 1968. Two one-lane roads built in 1949 (see below) degraded rapidly into eroded, high-center tracks that were seldom used. Except in the immediate vicinity of the observatory road, efforts to reach newly established fires presently require from one to several days. The assistance of the Mexican Army has been sought in fighting several large burns since 1974. Suppression efforts have been largely futile, since soldiers have mostly arrived several days later, after the flames had already spread across thousands of hectares.

During large burns, flames alternately smolder in logs, snags, or root crown burls when the humidity is high, then spread through brush and forests in dry weather, persisting for weeks or months (Francisco Mayoral, personal communication). As recently as 1989, two fires persisted for six weeks. In June 1996, a 6,000 ha burn persisted in the central Sierra for one month.

Cloud-to-ground lightning is a significant source of fire in the Sierra. The U.S. Bureau of Land Management lightning-detection system, which covers Baja California north of latitude 31°, records an average of 15 to 30 strikes per thousand hectares per year (Minnich et al. 1993). Although records do not exist, the frequency of fires initiated by lightning is apparently high, perhaps in the thousands per decade. In southern California, 2 to 4 percent of discharges initiate fires that require suppression action. The same percentage of lightning discharges in SSPM can account for the complex patch structure seen now in the Sierra (Minnich et al. 1993). Our best evidence of lightning-fire frequencies comes from color aerial photographs taken in 1991, which recorded 204 ash beds of current-year spot fires (ash is removed within one rainy season), with 190 occurring in mixed conifer forest. Only seven burns exceeded 8 ha (total 175 ha), while the remaining 197

burns accounted for only 218 ha. Most were far removed from roads and trails, and burned out on their own without being suppressed. Spot fires consumed litter beds but caused little disturbance to even prostrate shrubs and small trees.

The tree-ring record of fire (Burk 1991), which extends to 1800, shows little change in the rate of fire scarring during the past 200 years. This indicates that both grazing and efforts at fire control have had little effect on the fire regime in the Sierra. Simultaneous fire scars at multiple sampling sites indicate that large burns moved eastward from the west slope onto the plateau at Vallecitos in 1862, 1899, and 1920, and at La Grulla in 1860, 1880, and 1923. The intervals between burns is similar to those after 1925 in these areas. However, a few trees at most sampling sites also record other fires, perhaps lightning strikes or local "spot fires" similar to those recorded in the aerial photographs of 1991.

Fire Impacts on the Vegetation

Chaparral. The high frequency of fires (number of events/area) gives the Sierra's chaparral a complex patch structure, which is related to fire behavior and successional processes (Minnich 1983; Minnich and Chou 1997). Fire-perimeter data for SSPM suggest that fire occurrence in chaparral is time dependent, with minimum fire intervals being relatively long due to the gradual accumulation of fuel (Minnich and Chou 1997). This is seen in the non-random interlocking patch sequences with little overlap between burns. The time threshold for burning is a property set by the rate of fuel accumulation inherent in the vegetation, with stands younger than that threshold constraining the progress of burns. Thus, the evolution of patch mosaics created by fire is a non-random and self-organizing process, because the occurrence of one event is affected by past events, which in turn affects future events (Minnich and Chou 1997).

Due to the high continuity of fuel in chaparral, fires generally result in stand-replacement burns. Nearly all above-ground biomass is burned, and the shrub layer is even-aged during post-fire succession. It is typical for fires burning in old stands to stop for lack of fuel when they run into younger ones. The high frequency of burns in Baja California results in a fine patch structure, which helps to keep fires small (see plate 9). Burns frequently have braided, reticulate configurations of denuded land with numerous islands of unburned cover, which results from

the discontinuous spreading of flame fronts that merge and separate. "Creeping fires" are often observed in the field, with flame heights generally less than 5 m. The low intensity of fires is consistent with reported fire durations of weeks or months, because only small areas are consumed per unit of time. By comparison, fire suppression in California has resulted in the homogenization of the stand mosaic, stimulating ever-larger fires. Uncontrolled fires generally escape only in the severest weather, thus leading to higher magnitude fires and more complete denudation of chaparral (Minnich 1983; Minnich and Chou 1997). Large fires are frequently conflagrations—continuous flame fronts 10 to 30 m in height—which consume virtually all chaparral inside the fire perimeters.

Mixed conifer forest. Analysis of aerial photos and ground-based sampling shows that the Sierra's mixed conifer forests are mostly open and parklike. They consist of mature trees—as tall as 30 to 45 m—with few pole-sized trees and saplings, and open shrub cover (Passini, Delgadillo, and Salazar 1989; Minnich et al. in press). Point-quarter center transects (Cottam and Curtis 1956) and aerial photograph samples reveal that mixed conifer forests consist mostly of old-growth trees. Stand densities range from 50 stems per hectare in *Pinus jeffreyi* forest to 150 stems per hectare in *Abies concolor* forest. Most forests have a mixed-age structure, but some have a J-shaped size distribution, with maximum stem densities in the range of 0.7 to 1.0 m diameter at breast height (dbh). The density of saplings, i.e., stems less than 3 cm dbh, averages 160 stems per hectare.

Long fire intervals are attributed to the gradual buildup of a subcontinuous shrub cover, conifer recruitment, and litter accumulation (Minnich et al. in press). Long-term fuel accumulation encourages intense surface fires that selectively eliminate sapling and pole-sized trees in the understory, yielding old-growth *Pinus jeffreyi* forest. For example, field observations in two 1989 burns revealed that fire intensities were at times high enough to kill 60 to 80 percent of pole-sized trees, and 5 to 30 percent of canopy trees (unpublished data). Scorching of *P. jeffreyi* reached 10 to 20 m above ground, so that the dominance of that species may thus be related in part to fire intensities that favor its survival. The bark of *P. jeffreyi* is thicker and its canopy higher above ground fuels than those of either *Abies concolor* or *Calocedrus decurrens*. Moreover, the regeneration of *P. jeffreyi* may be stimulated by

ground fires intense enough to burn away litter and competing shrubs, while light ground fires inhibit the regeneration of *A. concolor* and *C. decurrens* (Barbour and Minnich, in press).

Examination of repeat aerial photographs reveals measurable regeneration of trees during post-fire succession (Minnich et al. in press). These succession chronosequences show an increase of 15 pole-sized stems per hectare after 50 years. In SSPM, forests that have not burned for more than 70 years support tree densities as high as 400 stems per hectare, similar to forests in California (Vankat 1970; Vankat and Major 1978; Minnich et al. 1995). The potential for stand thickening is seen in sapling densities two to four times that of overstory trees (100 to 600 per hectare). Over the long run, the rate of entry into the overstory class is balanced by the rate of mortality. Forests normally comprise mixed-age stands in which relatively few pole-sized trees join the canopy layer during successive fire cycles, and relatively few canopy trees die of fire or other factors. The density of mature overstory trees shows no statistical change over time. As in chaparral, the turnover of forest patches is non-random.

Historical descriptions of the Sierra's vegetation reveal that the composition, structure, distribution, and fire regimes of conifer forests are remarkably similar to those seen presently. In 1792, Longinos Martinez described pine forest along what is now a cattle trail between Valladares and La Grulla in words that would equally well describe the vegetation there today (Minnich and Franco-Vizcaíno, in press). In 1888, the Sierra's forests were examined in detail during an extraordinary 76-day survey by Col. D. K. Allen. Allen recorded nearly the same species composition and size-frequency distribution of tree diameters as were recorded in our transects (Minnich and Franco-Vizcaíno, in press). The Sierra's forests have lower tree mortality rates from drought and bark beetle infestations than those in southern California (Savage 1994).

The 50- to 55-year fire-rotation periods in SSPM are far longer than the estimated 4- to 20-year fire intervals in mixed conifer forests of California. However, long-term lightning discharge rates may be sufficiently high that most stands experience a mixture of both local and landscape fires. We therefore hypothesize that the disparity in fire-rotation periods is an artifact of spatial (fire mapping) versus site-specific data that relates to differences in the size class of fires being evaluated. The 50- to 55-year intervals calculated for SSPM are constrained by a

lower size limit of 5-hectare burns, while the shorter intervals estimated in site-specific studies reflect both landscape and spot burns. Spot burns, although numerous, have little spatial or ecological impact.

Experience with fire suppression in California indicates that controlling fires in the Sierra is likely to result in buildup of fuel and thicker, closer stands. In the San Bernardino Mountains of southern California, nearly 100 years of suppression has caused stand densities to increase from 100 stems per hectare in 1932 to 200 to 300 stems per hectare in 1992. Densities are locally as high as 500 stems per hectare (Minnich et al. 1995). Likewise, forests in the Sierra Nevada average 500 stems per hectare (Vankat 1970; Vankat and Major 1978; McKelvey and Johnston 1992). Forests in California also show an age-specific trend in which juvenile, pole-sized cohorts of such forests are heavily dominated by *Abies concolor* and *Calocedrus decurrens,* whereas mature, overstory cohorts are dominated by *Pinus ponderosa* and *P. jeffreyi* (Rundel, Parsons, and Gordon 1988; Barbour 1988; McKelvey and Johnston 1992; Minnich et al. 1995). Stand thickening and fuel buildup have also led to enormous canopy fires and replacement of conifer forest by chaparral and broad-leaf forests (McKelvey and Johnston 1992).

Fauna

The 1906 Biological Survey (Nelson 1921; Goldman 1916) produced the first general inventory of the Sierra's fauna. Although this study is dated, these accounts are significant because they describe possible pre-European distributions of many species and the subsequent decline of several species due to hunting.

The Sierra's vertebrate land fauna (see table 2) is similar to that of California. Common large mammals include mountain lions (*Felis concolor*), bobcats (*Felis rufus*), the Peninsular Range mountain sheep (*Ovis canadensis*), coyotes (*Canis latrans*), badgers (*Taxidea taxus*), and foxes (*Urocyon cinereoargenteus*). Nelson (1921) reports the mountains were "swarming" with rodents including jackrabbits (*Lepus* spp.), cottontails (*Sylvilagus* spp.), kangaroo rats (*Dipodomys merriami*), pocket mice (*Perognathus* spp.), desert woodrats (*Neotoma lepida*), Beechy ground squirrels (*Spermophilus beecheyi*), and Douglas squirrels (*Tamiasciurus mearnsi*).

The Sierra's forests contain the typical insectivorous and fruit-eating resident birds found in Californian forests, including the mountain

chickadee (*Parus gambeli*), juncos (*Junco* spp.), nuthatches (*Sitta* spp.), and several woodpeckers (*Picoides* spp., *Melanerpes* spp. (see table 3). Common birds of the chaparral are the wren tit (*Chamaea fasiata*), brown towhee (*Pipilo fuscus*), scrub jay (*Aphelocoma coerulescens*), California quail (*Callipepla californica*), and California thrasher (*Toxostoma redivivum*).

The species diversity of reptiles is much greater in the Sonoran Desert and coastal foothills than in the cold climates of the Sierra. Lizards and snakes inhabit mixed conifer forests; frogs are also found at wet sites. The reptilian fauna listed by Nelson (1921) is indistinguishable from that of California, and he hypothesized that fauna, as well as other terrestrial life forms, migrated into the geographically isolated peninsula from the north. An alternative view is that the post-Miocene breakup of the Baja California peninsula from Mexico led to the evolution of a strongly endemic herpetofauna (Murphy 1983). Still, there are subtle differences in the biota between SSPM and the mountains of California. For example, the Steller's jay (*Cyanocitta stelleri*) and the Clark's nutcracker (*Nucifraga columbiana*), both common in California forests, are seldom observed and apparently do not breed in forests on the Mexican side (Kratter 1991, 1992). The pinyon jay (*Gymnorhinus cyanocephalus*), which normally occupies pinyon forests and high deserts in California, has expanded its range into mixed conifer forests and subalpine *Pinus contorta* forests in the Sierra.

Among mammals, the Mearns tree squirrel (*Tamiasciurus mearnsi*) is considered endemic to the Sierra (Mellink-Bijtel 1991); it is related to the Douglass tree squirrel (*Tamiasciurus douglassii*) of the Pacific coast ranges from British Columbia to the southern Sierra Nevada. A bat (*Myotis milleri*) is also an endemic species (Mellink-Bijtel 1991). In addition, five subspecies of mammals, and eighteen subspecies of resident birds are endemic to the region (see tables 2–3; Mellink-Bijtel 1991; Grinnell 1928). The phenotypic differentiation of these species and subspecies suggests a lengthy period of isolation without gene flow from outside populations (Kratter 1991, 1992).

Annotated species lists of reptiles, insects, birds, heteromyid rodents, and bats of Baja California have been examined for Simpson's (1964) "peninsular effect," which predicts that species diversity (density) increases from the tip of a peninsula to its connecting point with the primary landmass (Taylor and Plannmuller 1978). But Brown (1987) suggests that species richness is not due so much to the isolat-

ing effects of a peninsula as they are to present habitat and vegetation distributions, which are functions of the immigration/extinction equilibrium. The northwestern part of Baja California, including the Sierra, tends to have greater species diversity in all these groups than other parts of the peninsula, probably because of the region's mesic habitats and heavy vegetation cover.

Rare and Endangered Species

Plants. The best-known endemic of the Sierra is ***Cupressus montana*** (see table 4), which covers an area of only 2,400 ha. Although populations have long been known from ledges and fractures on Picacho del Diablo, color aerial photographs taken in 1991 reveal new populations on the eastern escarpment near Cerro Venado Blanco, and in pinyon forests between this area and Picacho del Diablo and southward to Arroyo El Cajon. On the plateau, a few populations of *C.* ***montana*** occur along arroyos leading into La Encantada meadow. ***Garrya grisea,*** the only shrub endemic to the Sierra, is common in mixed conifer forest. ***Agave moranii*** is found only in the lower eastern escarpment and adjoining bajadas.

Two shrubs are very rare in the Sierra. The only known occurrence of ***Rhus kearneyi*** in SSPM is from Cañón del Diablo. This species is known elsewhere in the Tinajas Altas of Sonora and in the higher ranges of the Central Desert to as far south as Volcán Las Tres Virgenes (Cody, Moran, and Thompson 1983). *Cercocarpus ledifolius* is widespread in the western United States. However, its known distribution in northern Baja California (and Mexico) is a single summit east of the National Observatory, where it occurs within an area of about 30 ha.

All other endemic plants are annuals or herbaceous perennials; many are restricted to meadows and appear to be resilient under livestock grazing: ***Haplopappus wigginsii, Lesquerella peninsularis, Senecio martirensis, Mimulus purpureus, Ophiocephalus angustifolius, Astragalus gruinus,*** and ***Trifolium wigginsii.*** The latter two species are abundant at the Vallecitos meadows and appear to tolerate heavy grazing. Several endemics are restricted to steep, rocky slopes and crevices, especially on the high eastern escarpment. These include ***Haplopappus martirensis, H. pulvinatus, Hedeoma martirense, Heterotheca martirensis, Sphaeralcia martirense,*** and ***Stephenomeria monocephala.*** Other endemics occur in sandy soils and granite boulders of the forested plateau: ***Draba cor-***

rugata, Eriogonum hastatum, Hemizonia martirensis, G. diabloense, and *Galium wigginsii.*

Fish. Freshwater fish are nearly absent from the Sierra because permanent streams are scarce. However, several arroyos contain an endemic rainbow trout (*Oncorhynchus mykiss nelsonii*) that tolerates the warm water (27°C) in standing pools of arroyos during periods of very low runoff. Apparently the trout was originally found in the San Antonio branch of the Río Santo Domingo, but has since been introduced to other streams, such as the Río San Rafael (Henderson 1960).

Megafauna. By the time of the 1906 Biological Survey, hunting had already contributed to the decline or extinction of several big-game animals in Baja California, similar to the situation in California. However, conservation practices in recent decades have helped protect other species. The pronghorn antelope (*Antilocapra americana*), which once occupied large areas of the peninsula (Brown 1992), is now restricted to the Vizcaíno Desert (E. Mellink-Bijtel, personal communication). The last report of this species in adjoining San Diego County was in 1921 (Bond 1977). The mountain sheep once occupied most of the ranges on the eastern half of the peninsula, but was hunted for sport or slaughtered to supply mining camps and small towns with meat (Nelson 1921; Mellink-Bijtel 1993). Still, as many as 1,000 or 2,000 animals survive on the remote eastern escarpment of the Sierra (Aguilar-Rodríguez 1991). Nelson (1921) states that mule deer (*Odocoileus hemionus*) had become relatively scarce by the turn of the century. Presently that animal is fully protected from hunting within the national park and is common in the Sierra's forests.

The grizzly bear (*Ursus horribilis*) was reported as far south as the Sierra Juárez, but it was apparently not native to the Sierra (Nelson 1921). There are no reliable records of wolves on the peninsula, although Nelson (1921) indicates they must have been native. Spanish explorers of the eighteenth century did not refer to wolves during their explorations (Minnich and Franco-Vizcaíno, in press). The mountain lion is native to the Sierra (Henderson 1960). During their expeditions through the Sierra, both Linck (1766) and Serra (1769) reported that mountain lions had made their livestock restless on several nights (Minnich and Franco-Vizcaíno, in press). We have commonly seen mountain lion tracks in the Sierra.

The California condor (*Gymnogyps californianus*) was native to the Sierra, and it was observed or collected many times after 1879 (Wilber and Kiff, 1980), including during the biological survey (Nelson 1921). The Sierra provided the most favorable habitat for this bird because of the abundance of meadows, presence of native ungulates such as bighorn sheep and deer, the seasonally large numbers of cattle, and the existence of favorable nesting sites. The condors of northern Baja California had likely been an isolated population since the nineteenth century, because by that time condors had already disappeared in adjacent areas (Wilber and Kiff 1980).

The SSPM condor may have had an annual nesting cycle similar to that of the California population. Condors probably nested in the coastal ranges, which had less severe winter climates, and the nonbreeding birds moved to summer feeding and roosting areas at higher elevations. Although it was reported to exist in the range as late as the 1930s, it is now extinct (Koford 1953; Henderson 1960, 1964; Robinson 1975; Wilber and Kiff 1980). The demise of the condor is attributed to prolonged drought and a lack of food brought about by a decline in domestic and native ungulates following overgrazing in the 1920s (Koford 1953). Its extermination has also been attributed to slaughter for sport and the use of its quill feathers as receptacles for gold dust (Henderson 1960).

HISTORY AND LAND USE

Although the Sierra was first observed by Europeans from a distance during sea voyages to the northern Gulf of California by Ulloa (1539) and the Jesuit fathers Eusebio Francisco Kino and Juán María Salvatierra (1701), it was first explored and settled in a relatively brief period during a turbulent time in California mission history in the late eighteenth century (Meigs 1935). Jesuit control of the peninsula was abruptly terminated by their expulsion in 1767. They were replaced by Franciscan and Dominican missionaries. The Spanish crown was also intent on expanding its sphere of influence northward from the deserts of Baja California to Alta California, to deflect the threat of foreign encroachment.

The first European to visit the region was the Jesuit Wenceslaus Linck, minister of the San Borja mission in central Baja California (Bur-

rus 1966; Meigs 1935). In 1766, Linck crossed the southern Sierra and explored the deserts east of the range. After the Jesuits left in 1768, the region was turned over to the Franciscan order, which organized an historic expedition across northern Baja California to San Diego. This journey was part of an effort to resist encroachment by the Russians, who were extending their settlements from Alaska down the Pacific coast (Bolton 1927). The Franciscans traversed the Sierra's western margin in 1769 (Bolton 1927: 6; Meigs 1935: 11). Subsequent explorations of the Sierra by Longinos Martínez (1792) and Arrillaga (1796) were undertaken when the Dominicans established the Mission San Pedro Mártir de Verona (Minnich and Franco-Vizcaíno, in press).

The Kiliwa Indians and Mission San Pedro Mártir de Verona

When northern Baja California came under Dominican control, the friars first established missions along the coast, then expanded the frontier to the inland mountains (Meigs 1935; Tiscareño and Robinson 1969). In 1794 the Dominicans established the Mission San Pedro Mártir de Verona at a "watered forest-rimmed meadow," named Casilepe. A recent discovery of foundation stones indicates this site was at the north end of La Grulla meadow (Foster 1992). Casilepe proved to be unsuitable due to the severity of climate. Soon thereafter, the Dominicans selected a final, more temperate site at a lower altitude (1,550 m) along Arroyo El Horno, 10 km east of San Isidoro (see figure 1).

The Kiliwa, who resisted missionization efforts of the Dominicans, belong to the Yuman linguistic group (Meigs 1935, 1939). They were nomadic hunters and gatherers who used much of Sierra and did not practice agriculture (Meigs 1939; Owen 1963). They continue to live along the northwestern flanks of the Sierra (plate 10). (The related Paipai also live in the adjoining southern Sierra Juárez.) Hinton and Owen (1957) found the Kiliwa living in the Sierra in three rancherías numbering about sixty people, with most inhabitants along Arroyo de León, an area they consider as their "reserve" set up by the government. Currently nearly one hundred persons, nearly the entire extant population, inhabit Arroyo de León, which is part of Ejido Kiliwas; its lands are the property of the community (Arnulfo Estrada, personal communication).

Their principal foods are agave hearts (*Agave deserti*) and *Yucca schidigera*. Mescal roasting is practiced in the northwestern basins of

the Sierra. Fires occasionally escape in the chaparral from the roasting pits. Whether the Kiliwa deliberately burn chaparral or other plant communities for specific purposes has not been documented. The high country of SSPM proper is used for the harvest or hunting of pinyon nuts, acorns, deer, rabbits, and other resources. Corn and squash are cultivated in a few plots. Some Kiliwa also work as cowboys for surrounding ejidos (Hinton and Owen 1957). According to Kiliwa informants, the Sierra's forested plateau was not permanently inhabited by Indians because of the winter cold (Meigs 1935, 1939).

The Mission San Pedro Mártir de Verona was short-lived (1794–1806), but was unique among the missions of the Californias because it was devoted to livestock grazing instead of agriculture (Foster 1991). The mission was of typical Dominican design, consisting of a series of adobe buildings, some with stone cobble foundations. These were connected by a perimeter wall that protected the inhabitants during periods of unrest. Written records relating to the mission are scant. When Arrillaga visited San Pedro Mártir de Verona on his way to explore the port of San Felipe, he reported that the mission sent cattle to La Encantada meadow for summer grazing. Cattle were also grazed at the other major meadows (Meigs 1935). The population at the mission was modest, numbering only 94 in the year 1801. Few Indians were available for the mission because much of the area was without permanent rancherías. The mission managed several crops of wheat, corn, and beans, irrigated by ditches from two permanent springs.

The Dominicans endured a troubled existence, as hostile Indians often raided the outposts, killing men and driving out cattle. The Indians were also decimated by disease. The mission was closed in 1806, having operated only twelve years. Indeed, the survival of the Kiliwa was no doubt related to the rapid failure of Dominican missionization efforts in the Sierra.

Livestock Grazing and Mining

The Sierra has been used for summer pasture since the establishment of the Mission San Pedro Mártir two centuries ago (Henderson 1960, 1964; Meling-Pompa 1991a, b). After the mission period, Dominican landholdings were granted or sold to local citizens, usually Mexican government officials and military officers. They began subsistence cattle ranching in the Sierra, mostly on open range. The gold strikes at

Real del Castillo (1872) and El Alamo (1889) in the Sierra Juárez, and at El Socorro and Valladares (1874) on the west base of the Sierra San Pedro Mártir, encouraged the running of larger cattle herds and commercialization of operations.

The rich Socorro placers on the west slope of the Sierra were the scene of a large-scale hydraulic mining operation. During the 1906 Biological Survey, Nelson (1921) described "a well-made trail" and a "large ditch" on the Sierra's northern escarpment, the function of which was to divert waters of the Río San Rafael to the Socorro placers. The ditch, which spanned a length of 18 miles (30 km), was constructed in 1893 by Harry Johnson, a resourceful miner from Texas. The tailings from this strike may still be seen today at El Socorro (see figure 1). The Johnson ranch was burned by rebels during the revolution in 1911.

Salvador Meling, who immigrated to northern Baja California from Norway, helped to repair the ranch and married into the Johnson family in 1913. The Meling family now operates Rancho San José, a cattle and guest ranch in the foothills of the western Sierra (Robinson 1975). By the end of the nineteenth century, gold was being mined mostly from placers along the western edge of the Sierra at such camps as El Socorro, Valladares, Buena Vista, and Las Chollas. Political and economic disruptions during the early Mexican Revolution suspended mining, but thereafter placers were reworked from 1920 to 1940 (Henderson 1960).

Cattlemen of the early nineteenth century were the ancestors of the cattlemen who now live in the region. Open-range cattle grazing in the Sierra has continued to this day, largely under control of the same families. A comprehensive list of cattlemen operating from Valle San Telmo and Santo Domingo who grazed cattle on the Sierra from 1828 to 1915 has been compiled by Meling-Pompa (1991a, b). Francisco Mayoral, a SARH employee at the Parque Nacional San Pedro Mártir since the 1940s, also made reference to that list during an interview in 1990.

Grazing of sheep in Baja California began ca. 1910, when it was prohibited from southern California mountain pastures in the newly developed system of U.S. national forests. American investors organized sheep drives, under Basque shepherds, that began in August near Tijuana and returned in October from as far south as the Sierra. According to Meling-Pompa (1991a, b), sheep were abundant in the Sierra between 1911 and 1964, after which they were "prohibited"

from the Sierra, apparently because of conflicts with cattlemen. However, Francisco Mayoral (personal communication) indicated that sheep were still being driven into the Sierra as late as 1975.

PRESENT LAND USE AND OWNERSHIP

The Sierra's lands are primarily divided between the national park and ejido (communal) holdings. The eastern escarpment is essentially not utilized, but lies within the boundaries of the Ejido Plan Nacional Agrario. The national park covers ca. 60,000 ha, which includes most of the north and central plateau from Cerro Venado Blanco in the north through the meadows at Vallecitos, La Grulla, and La Encantada in the south (see figure 2). Moving clockwise, the park boundaries are circumscribed by 8 localities: (1) 31°05′ N, 115°35′ W; (2) 31°05′ N, 115°27′ W; (3) 31°00′ N, 115°22½′ W (Picacho del Diablo); (4) 30°57′ N, 115°18′ W; (5) 30°56½′ N, 115°16′ W; (6) 30°52½′ N, 115°17½′ W; (7) 30°49′ N, 115°30½′ W; (8) 30°58′ N, 115°38′ W, then back to point 1. The National Forestry Reserve covers a larger area that includes both national park and ejido lands. The reserve is bounded by the 1,000 m contour and includes the entire Sierra from Valle Trinidad south to 30°, as well as some mesas and foothills to the west of the range.

Cattle operations in the Ejido Bramadero are under the control of 20 to 30 commercial owners. The ejido, which covers an area of 300,000 ha, mostly on the west slope of the Sierra, is based near Sinaloa in the center of Valle San Telmo; it includes a number of dispersed satellite ranches on the Sierra's western base: Santa Cruz, El Potrero, San Antonio, La Concepción, Valladares, and La Suerte. The primary access of La Suerte to the coast is along a road farther south to near Lázaro Cárdenas. Most satellite ranches are located near permanent streams and have developed rustic diversion systems to irrigate small areas of fruit trees and grain crops. Two other settlements, Rancho San José (Meling Ranch) and San Rafael (Mike's Sky Ranch), are privately held "small properties" that graze cattle but are also managed as tourist guest ranches (Robinson 1975).

According to Meling-Pompa (1991a, b), the present cattle-grazing economy is much like that practiced from 1828 to 1915. The Sierra is used exclusively for summer pasture by white-face cattle; this resource

provides 50 to 75 percent of the potential for cattle production in the ejidos. Cattle can survive winter better in the lowlands if they have fed well in the mountains during the previous summer. During the winter rainy season, cattle graze on annual herbaceous cover and feed on crop residues in the agricultural zones in the basin of San Telmo and along Arroyo Santo Domingo basin. Once the wildland vegetation has cured, cattle are driven into the mountain meadows during May and June, the timing depending on rainfall during the previous winter. In late spring, cattle are rounded up and bathed, vaccinated, deparasitized, branded, and marked. Afterwards, they are herded up into the mountains in drives that last three to ten days. In dry years since the 1970s cattle have occasionally been hauled up by truck.

The primary pasturelands on the Sierra's plateau are the large meadows of La Grulla, La Encantada, Santo Tomás, Santa Rosa, and Vallecitos. The meadows in the vicinity of Cerro Venado Blanco, on the Sierra's northern end, are too small to justify bringing cattle there. In 1987, after a wet winter, we found these small meadows to be almost untouched by livestock. However, they were heavily grazed during the drought of 1988–1990.

Cattle drives follow four primary trails: (1) Rancho Santa Cruz eastward to La Grulla and La Encantada meadows; (2) Rancho El Coyote to the northern end of Sierra Corona at Corral de Sam; (3) Rancho San Isidoro (abandoned) to Mission San Pedro Mártir and Santa Rosa Meadow; and (4) La Suerte to Arroyo Santa Eulalia in the southern Sierra. Meling-Pompa (1991a, b) indicated that cattle must be watched constantly while they are in the park and they are frequently moved to better pasture. The cattle remain until late October, when intense cold begins; they are then rounded up and driven downwards along the same trails to the same ranches from whence they came. The more experienced cattle seem to know the mountain and follow the trails without having to be driven.

Cattle ranchers claim that sheep undermined the cattle-grazing economy due to the divergent management practices for sheep and cattle (Meling-Pompa 1991a). The ranchers assert that sheep damaged the grazing resource because they would bite to ground level and were grazed in large flocks that were moved only when pastures were consumed, whereas cattle graze in a dispersed manner and do little damage to plant roots and young pines. Francisco Mayoral (personal communication) indicated that a grazing tax was placed upon cattlemen during

the 1960s and 1970s in response to overgrazing. However the tax proved unenforceable, and as late as 1975, when as many as 4,000 to 5,000 cattle and 10,000 sheep were herded in SSPM, grazing remained uncontrolled.

Access

Until the late twentieth century, the Sierra was accessible only by foot or on horseback, mostly along the trails used to drive cattle between the mountain meadows since Dominican mission times. The area was accessible from the east via ancient Indian paths along Cañadas El Cajon, Huatamote, and Agua Caliente (Robinson 1975). In 1949, a primitive road was constructed from Rancho San Rafael to Corral de Sam in the northwestern corner of the plateau (Henderson 1964). Another was established from Rancho San José to the present site of SARH facilities at La Puerta. These roads were constructed ostensibly to exploit the timber on the plateau, but logging was prohibited in the national park before sawmills could be established (Henderson 1964). Both roads were one-lane rutted tracks that few dared to travel. Access into SSPM was more efficient by foot or on horseback.

An improved graded road was built in 1968 to support the National Observatory; it followed the old Meling road to La Puerta, then wound through Vallecitos to the telescopes. This road is now the primary access to the north-central Sierra. Secondary roads were built north from the main road along Sierra Corona and from Campo Forestal to the upper reaches of Arroyo San Rafael, and south to Cerro Botella Azul and La Tasajera. Slopes north of Arroyo San Rafael and in the southern half of the range, including the pastures of La Grulla and La Encantada and the mission are still inaccessible to motor vehicles.

The Observatorio Astronómico Nacional de San Pedro Mártir

Analysis of meteorological satellite imagery reveals that the northern part of Baja California is one of the three least cloudy regions in the world (Mendoza, Luna, and Gómez 1972). Beginning in 1967, the Mexican National Autonomous University (UNAM) built a series of telescopes on a 2,800 m summit (31°02′30″ N, 115° 27′30″ W), which comprises the National Observatory (Mendoza, Luna, and Gómez 1972; Alvarez and Maisterrena 1977; Alvarez 1981; Tapia 1992).

The observatory is supported by nearby maintenance facilities and living quarters. Radio towers have been erected on both the western and eastern rims of the plateau for radio communications between observatory personnel and the Institute of Astronomy's headquarters in Ensenada, as well as with national park and other agencies. The primary road is constantly maintained to support nearly daily transportation of staff and researchers between Ensenada and the observatory.

Agriculture in the Eastern Basins

Commercial irrigated agriculture has been implemented in scattered localities in the desert basins east of the Sierra. These include Santa Clara in Valle Santa Clara and the settlements of Ejido Plan Nacional Agrario, El Chaparral, Rancho Algodón, and Agua Caliente in Valle Chico. The Sierra's precipitous eastern escarpment virtually isolates these ranches from activities on the plateau.

Population

Available census data (Instituto Nacional de Estadística, Geografía e Informática 1983) are too generalized to determine population characteristics specific to the Sierra. Hence, it is only possible to estimate the local population on the assumption that most ranches comprise a few families. Since there exist in the vicinity of the Sierra only five major ranches on the west side and four ranches on the east side, we estimate that the total population of the region is several hundred people. Some smaller ranches appear to be abandoned. With the exception of personnel at the National Observatory, the Sierra plateau proper has no permanent inhabitants.

The nearest village-size population centers to SSPM are Ejido Sinaloa in the center of Valle San Telmo and the mission village of San Telmo. Both settlements are on the observatory road and number perhaps 500. Along the coastal highway, a number of villages and towns have grown rapidly in association with extensive commercial tomato plantations. They include Colonet, Lic. Gustavo Díaz Ordaz, Rubén Jaramillo, Camalú, Colonia Vicente Guerrero, Lázaro Cárdenas, and San Quintín. Another large population center, Valle Trinidad, lies to the north. This basin is noted for irrigation agriculture, dry farming of grains, and fruit horticulture. The Sierra was formerly accessible from

Valle Trinidad via a road between Rancho San Rafael and San José, but this section was destroyed by floods in 1979 and 1980.

POTENTIAL CONFLICTS OVER THE BIOSPHERE RESERVE

The Sierra's meadows have been used for summer pasture since the establishment of the Dominican mission system in the late eighteenth century. Hence, under the framework of the "Mexican modality" in biosphere reserves, establishment of the San Pedro Mártir Biosphere Reserve needs to accommodate the grazing economy. The rural population has a long-term understanding of the natural environment of the Sierra, including virtually every ecological issue of a reserve addressed in this report. The creation of a reserve will require that scientists, land users, and managers acquire a mutual understanding of the potential social, political, and ecological conflicts of the region. Sustainable land use on the Sierra will require the development of a database on the impacts of cattle grazing in relation to vegetation, wildland fire, and management of wildlife in a biosphere reserve. Unfortunately, there has been tension between land users and management agencies in the past concerning these impacts, in part because scientific data on the effects of cattle grazing are lacking.

During the past decades, SARH (Francisco Mayoral, personal communication) attempted to regulate livestock numbers within the carrying capacities of the major meadows. In turn, the cattle ranchers have attempted to improve the range condition of the national park. There was also an attempt by cattlemen to create an association for the conservation of the Sierra, but the petition was "denied by the authorities" (Meling-Pompa 1991a). However, an agreement was established between cattlemen and SARH whereby cattlemen would participate directly in the infrastructure works necessary to bring about controlled exploitation of the pastoral resource, such as fencing pastures and corrals, building watering troughs, reseeding meadows, and controling soil erosion. Cattlemen have also cooperated with forest authorities in fighting fires, feeding personnel, and providing beasts of burden. The principal meadows (La Encantada, La Grulla, Santa Rosa, Santo Tomás, and Vallecitos) have been partitioned by the ejidos.

Impacts of Cattle Grazing

The entire Sierra is exposed to some degree of grazing because stray cattle wander from the primary herds in the meadows, usually along trails connecting the meadows (Meling-Pompa 1991a). The intensity of grazing ranges from modest in the northern Sierra, where meadows are small, to intense in areas immediately adjacent to the larger meadows of Vallecitos, La Grulla, and La Encantada to the south. Some fenced areas are primarily used as horse pastures. Cattle exclosure experiments at our lower forest, upper forest, and meadow sites have provided preliminary data on carrying capacities that may help reconcile difficulties between ejidatarios and SARH (Barbour et al. unpublished data). More research will no doubt be necessary.

Forests

Data obtained in small areas fenced to exclude cattle suggest that the intensity of cattle grazing in forests is low and has no measurable effect on herbaceous and shrub cover (Barbour et al. unpublished data). Cattle do not dally in forests because herbaceous cover is limited by summer drought (mostly less than 2 percent). Neither do cattle affect the recruitment of conifers. Sapling counts at the Sierra Corona horse meadow and at an eight-year-old government exclosure (COTECOCA) at Vallecitos failed to show consistent differences in sapling densities inside and outside the perimeter fences. Sapling densities of 100 to 600 per hectare in 25 forest samples is a further indication that livestock grazing does not significantly affect regeneration of forests.

Field observations in SSPM and in the Sierra Juárez, indicate that most shrub species in the chaparral and mixed conifer forest are unpalatable to livestock (Minnich and Bahre 1995; Freedman 1984). When meadow forage was scarce during the drought of 1988–90, we found cattle skeletons in areas with permanent water (they did not die of thirst), indicating livestock would avoid shrubs even when herbaceous cover was scarce.

Meadows

Our best quantitative information comes from Vallecitos. Cover and biomass were low in both exclosures and controls during the drought

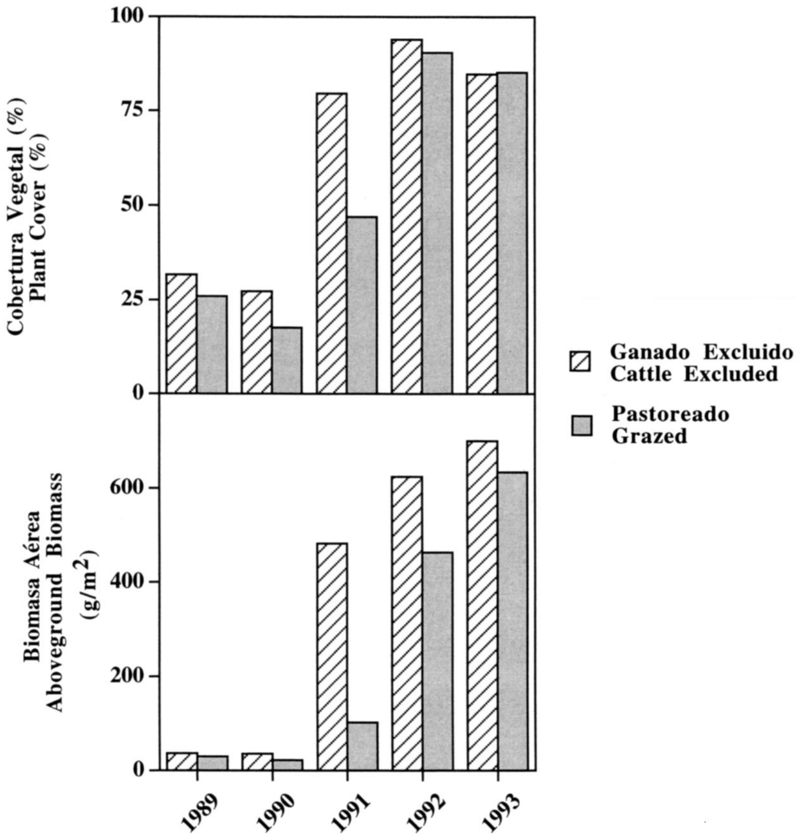


Figure 6. Effect of excluding cattle on above-ground biomass and plant cover of the herbaceous community in a Vallecitos meadow.

years of 1989–90 (see figure 6). However, only one year of cattle exclusion during the drought had a significant effect on both cover and biomass (1990 data show 60 percent more cover and 50 percent more biomass in exclosures versus controls). During years of normal or above-normal precipitation (1991, 1992, 1993), biomass increased by an order of magnitude both inside and outside of exclosures, but again biomass was greater in cattle exclosures by an average of 50 percent. Plant cover was also 14 percent greater in cattle exclosures during those years. Cattle remove biomass mostly from wet meadows, which do not contribute to fire hazard because they are wet. In drought, the drying of meadows is paralleled by lower fuel production in the forests.

Some 116 flowering plant species occur in Vallecitos meadow, but only about a dozen low-growing herbaceous perennials contribute significant cover and biomass: *Aster occidentalis, Eleocharis pauciflora, Muhlenbergia richardsonis, Potentilla wheeleri, Trifolium wigginsii* (a Sierra endemic), and several species of *Carex* and *Juncus.* We have noticed large fluctuations in the frequency of some of these species from year to year, but these variations appear to reflect annual and seasonal amounts of precipitation far more than they reflect grazing pressure. In our exclosures, four years of cattle exclusion had no effect on species composition.

Excluding cattle for longer periods appears to favor the establishment of native bunch grasses. We were able to study an abandoned COTECOCA exclosure constructed in 1984 to determine carrying capacity. The dominant species in this exclosure were several bunch grasses (*Koeleria cristata, Sitanion hystrix,* and *Stipa* spp.), in contrast to forb dominance throughout the grazed portion of the meadow. Biomass within this exclosure, measured eight years after cattle had been excluded, was more than twice the biomass in our four-year-old exclosures that same season.

Research that measures the relationship between cattle production and plant growth shows that, in most cases, cattle production can be increased while still moving toward sustainability, typically through a pasture-rotation system. This is accomplished by rotating cattle from area to area, leaving enough biomass to permit the maximum possible recuperation of the vegetation. If unmanaged, cattle tend to crop high-quality forage closer to the ground rather than low-quality forage. The result is that low-quality, undesirable plants have the advantage during the growing season. Using grazing trials in controlled conditions, researchers can determine the optimum amount of standing biomass to leave for maximum beef production without long-term negative effects of overgrazing.

We can conclude that moderately grazed wet meadows, such as Vallecitos, have been degraded to some extent in cover, biomass, and species diversity by cattle grazing. However, the rapid buildup in biomass after normal rains returned in 1991 shows that meadow species are very resilient. The COTECOCA plot also demonstrates that palatable perennial bunch grasses may also come back within a decade. Resilience is not characteristic for all meadows, and certainly not for dry meadows such as portions of La Grulla and La Encantada.

Wildland Fire

Tensions also have existed between government foresters and ranchers concerning wildland fire. In Baja California both federal and state agencies responsible for forest management have been all too eager to adopt fire-suppression policies without recognizing that attempts to protect forests from fire will likely be counterproductive. In Mediterranean regions, fire has long been used by cattlemen as a management tool to set back vegetation from advanced successional states to more open early-seral stages that have herbaceous forage (Minnich et al, 1993). According to Meling-Pompa (1991a, b), the Sierra's ranchers recognize that fire has always been present in the Sierra and have deliberately burned chaparral and meadows to improve access and forage. However, fire protection has been emphasized in recent years, and SARH foresters have even enlisted the aid of ranchers in firefighting.

In recent years, increasing pressure has been placed on cattlemen to refrain from setting fires. Moreover, since prosecutors have presumed that most fires are initiated by man, ranchers might be punished just because fires occur on their land. Because lightning is a more important source of fire than has been realized, false accusations are inevitable.

Large and catastrophic fires may result if fire suppression is instituted. This will offer little advantage to cattlemen or the mountain's ecology. Small burns improve local forage and access, whereas large fires cause cattle to become dispersed or lost and leaves the area without pasture (Meling-Pompa 1991 a, b). Conversely, an unmanaged fire regime on the Sierra's plateau poses little threat to structures because the Sierra is not permanently inhabited. Only the observatory should be protected, but its protection should not mandate fire control throughout the Sierra, nor would such an effort be desirable for reasons discussed previously.

In a future San Pedro Mártir Biosphere Reserve, scientists, land managers, and ranchers should be exposed to alternative views of wildland fire with respect to the grazing economy and its influence on natural ecosystems. Hence, it is imperative that managers consult with ranchers for knowledge of winds, annual climate shifts, and past fire histories (Gómez-Pompa and Kaus 1992). Foresters should also critically examine the "well-managed" status of their own forests, as well as the mistakes made in a similar ecosystem (i.e., California) because of fire suppression. Indeed, a passive response to wildfire and controlled

burning of mature vegetation may be a good option for management in a region where natural fire has shaped landscapes.

Logging

At the symposium held in December 1995, the leadership of the Ejido Bramadero, which holds parts of the Sierra's western escarpment and runs cattle on Vallecitos meadow, declared that the ejido was seeking a permit for "phytosanitary" logging, to remove trees infested with mistletoe (*Phoradendron* spp. and/or *Arceuthobium* spp.) or bark beetles (*Dendroctonus* spp.) (Sierra 1996). In June 1996, it was discovered that a crew of American loggers was using heavy equipment to improve a road, apparently within the national park, in order to transport logs to Ensenada. This activity was reported to the Ministry of the Environment (SEMARNAP) in Mexico City and the State Delegation of the Federal Prosecutor for the Environment (PROFEPA). A commission of experts arrived from Mexico City to take stock of the situation, but they were unable to determine, due to ambiguities in the legal description of the national park boundaries, whether the parcel to be logged was within the ejido or inside the national park. But the agents of PROFEPA determined that trees had been marked for cutting without the approval of the appropriate government agencies, and the logging permit was rescinded until further notice (Oswaldo Santillán, personal communication). At present, there seems to be an overlap between the ejido and park boundaries. Any ejido land within the park will be subject to the park regulations.

Alternative small-scale logging practices may be a useful supplemental tool in the sustainable management of SSPM forests on ejido lands, and perhaps in the park, but on a very limited basis. Studies in California have shown that clear-cut logging of areas greater than 2 ha is incompatible with the health of Mediterranean mixed conifer forests because the development of mature forests is dependent upon the selective mortality of saplings and pole-sized trees rather than the commercially valuable old-growth trees. Removal of overstory trees invariably leads to the establishment of chaparral and dense, young-growth forests with high fire hazard. This enhances the potential for catastrophic canopy fires and degradation of the ecosystem.

Cutting of dead trees could threaten the endemic bat *Myotis milleri*, which apparently requires them for roosting places (Mellink-Bijtel 1991). Unfortunately, the Mexican federal government is promoting

Park headquarters, San Pedro Mártir National Park.

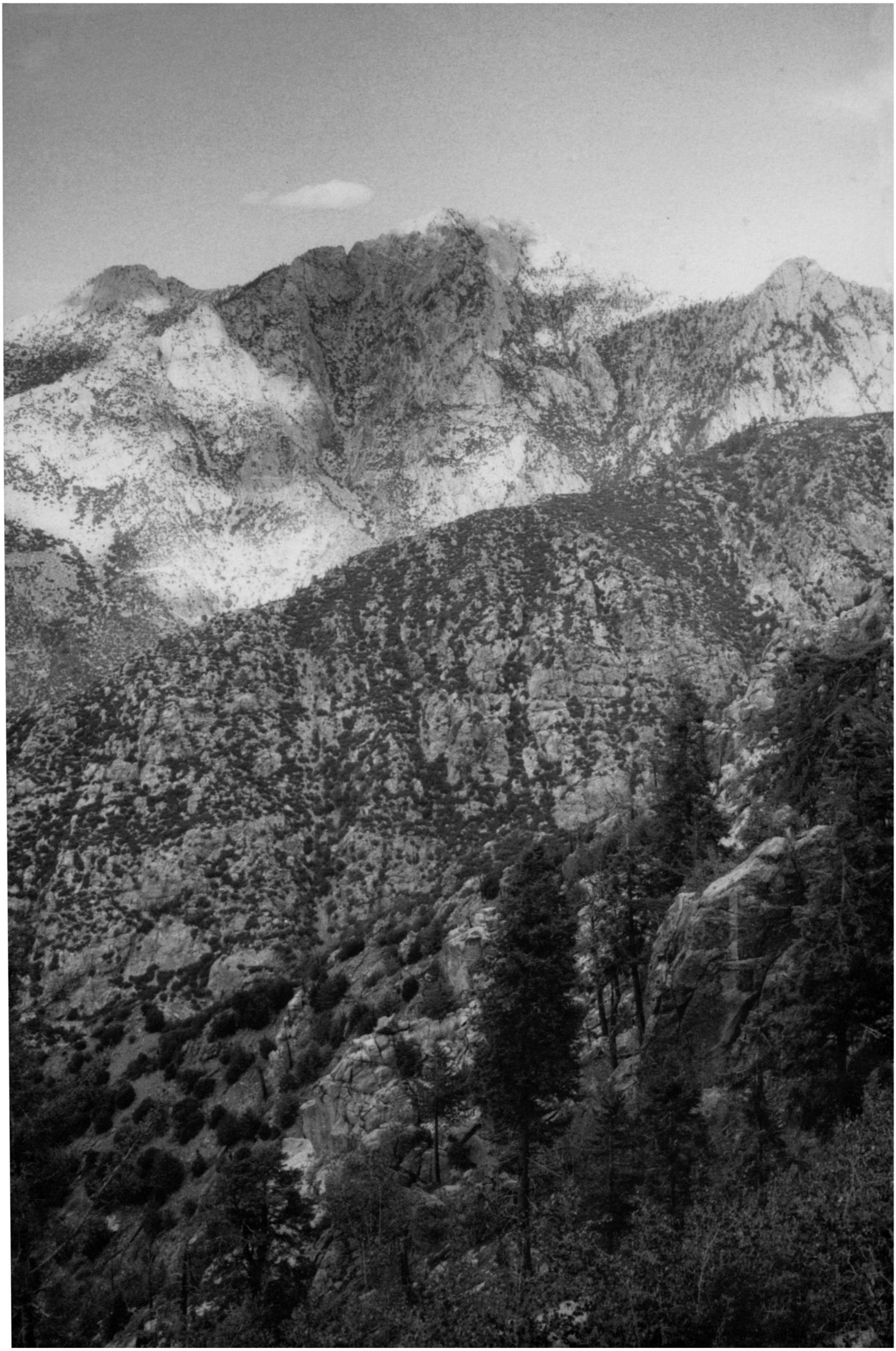
Jeffrey Pines, San Pedro Mártir.

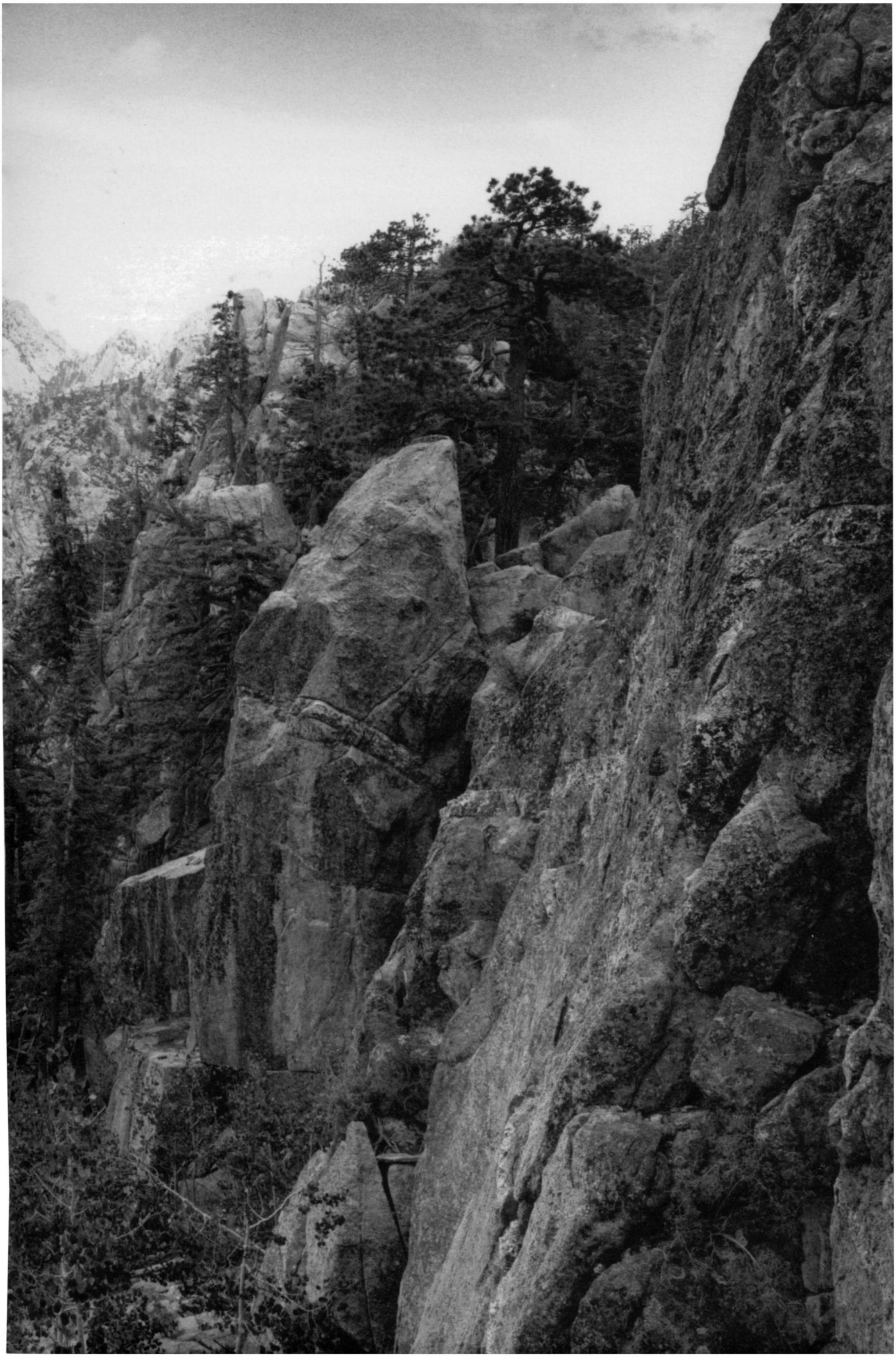
Grazing, San Pedro Mártir.

Jeffrey Pines, San Pedro Mártir.

Picacho del Diablo, San Pedro Mártir, next two pages.

(All photographs by Leland Foerster)





legislation that would liberalize current logging restrictions throughout the country. Establishment of the proposed biosphere reserve would serve to rationalize economic activities such as logging and grazing. Logging would still take place as planned in the ejido lands on the forest fringes, but a sufficiently large proportion of overstory trees would be left to assure the sustainable use of the Sierra's logging resource and the survival of the old-growth forest and its associated species.

Wildlife Management

Although several large mammals and the California condor have become locally extinct during the past century, the Sierra's isolation and pristine landscape have preserved the rich diversity of wildlife in the region. A potential conflict in a biosphere reserve will be the hunting of megafauna, which tend to have low reproductive rates. Hunting is prohibited within the national park, but is permitted outside the park on the eastern escarpment and southern third of the range. The development of a game management system will require compromise between the conflicting needs of land managers and users.

The Sierra's primary game animal in recent decades has been bighorn sheep living on the eastern escarpment. Controlled hunting of this animal, under authority of the Mexican Ministry of the Environment, has been permitted as recently as the late 1980s (Aguilar-Rodríguez 1991; Mellink-Bijtel 1993). Sheep hunting apparently led to minimal conflict with cattle ranchers because of the virtual isolation of the eastern escarpment from cattle operations on the plateau. But sheep hunting was banned by presidential decree in 1990 because of conflicts among wildlife protection groups and hunting associations (Mellink-Bijtel 1993). The decree requires that the sheep population be properly studied and a management plan be instituted before the hunting ban can be lifted. Deer are common throughout the forest plateau, but are not extensively hunted because most populations exist within the national park. However, the extent of poaching within the national park is unknown.

Protection of the Kiliwa Indian Culture

As a result of their historical isolation, the Kiliwa Indians, as well as the neighboring Paipai in the southern Sierra Juárez, are the last native

people to speak their languages and practice a hunting-and-gathering economy in the Californias. The cultural and social heritage of the region has been documented by programs of the National Institute of Social Research (IIS) of the Autonomous University of Baja California and the National Institute of Anthropology and History (INAH). This research complements the database of the MAB project (Bendímez-Patterson 1991) and includes locating and recording of archaeological sites, photographically recording rock art, and recording the oral information of indigenous peoples with a view toward searching for strategies for sustainable management consistent with the ecological resource base of the region.

DEVELOPMENT, STRUCTURE, AND MANAGEMENT OF A BIOSPHERE RESERVE

The Sierra San Pedro Mártir had remained relatively isolated until the opening of the observatory road in the 1970s. The impact of livestock grazing on biotic resources has been small, and it therefore appears to be compatible with sustainable use of the region's diverse resources. Dominant species in forests, meadows, and chaparral appear well adapted to periodic fire, browsing, and geomorphic disturbances.

The Sierra has been isolated not only because of the rugged and inaccessible nature of the region, but also as a result of the broader trends of economic development in northern Baja California. During the twentieth century, urban and agricultural growth has been concentrated in the rich Mexicali Valley and the border cities. However, the opening of the transpeninsular highway contributed to rapid growth of agriculture and establishment of ejidos and villages along the San Quintín coastal plain and San Telmo Valley.

The observatory road, which opened the region to the outside world, presents both threats and opportunities. Threats from fire suppression, economic development, and increasing recreation pressure may result in irreversible changes that will make the Sierra's forests indistinguishable from forests in the United States. These threats may become opportunities in a biosphere reserve if an institutional infrastructure were to be established that includes the rural population, land managers, and scientists. Such an infrastructure could help in the development of a sustainable system for the protection of these extraordinary ecosystems unique to Mexico.

Indeed, institutional resources are already in place for a biosphere reserve. Portions of the Sierra have been administered both as a national park and as an "astronomical reserve" by the former Ministry of Agriculture (SARH). Moreover, many research institutions in northern Baja California and the adjoining U.S. have conducted research on the geology, terrestrial biology and ecology, conservation, anthropology, archaeology, and history of the Sierra (see appendix).

The "International Conference on the Potential of the Peninsular Range of the Californias as a Biosphere Reserve" was held in Ensenada in March 1991 (Franco-Vizcaíno and Sosa-Ramírez 1991). Support for a biosphere reserve in the Sierra was expressed by all sectors that attended the conference. However, the concept of a cluster of biosphere reserves on five mountain parks along the Peninsular Range on both sides of the international border may have been too ambitious to gain confident support among participants.

Some felt that efforts toward a binational biosphere reserve should proceed cautiously because the coordination of efforts in both countries would be strained by differences in their economic structures and attitudes toward conservation (Ojeda, Espejel, and Sánchez 1991). It is likely that these objections will be less compelling as the economy of the border region becomes more integrated as a result of the North American Free Trade Agreement.

For MAB Mexico, a key aspect of the biosphere reserve concept has been the integration of conservation and rural development such that researchers and protected-area managers take into account the concerns and aspirations of the local populations (Kaus 1996). Corresponding research programs are encouraged to include studies that address these local and regional concerns and provide informed and practical recommendations for long-term management of the area. In turn, it is hoped that local people will take part in management and research activities, with the expectation that this process will facilitate the extension of conservation practices to the surrounding area. For these reasons, the nomination of the Sierra as a biosphere reserve under the UNESCO and MAB Mexico programs will require a local regional base of support for the reserve and the potential for local benefits from its presence. The nomination process will also require a comprehensive and cohesive research program, whose members can serve in an advisory capacity and assist in the elaboration of a management plan for the reserve (Kaus 1996).

During the second symposium in December 1995, the ranchers declared that they would not support any initiative for the Sierra that runs contrary to their interests and warned that the well-being of their families depends upon diversification of their economic activities, such as guiding quail-hunting and trout-fishing parties and logging (Meling-Pompa 1996). (It should be noted that some ranchers in other ejidos that also run cattle in the Sierra have subsequently indicated their support for the initiative.) But it was pointed out that establishing a biosphere reserve may actually serve the ranchers' interests, because sustainable use of natural resources is encouraged in biosphere reserves, but the only economic activities permitted in national parks are those related to tourism. Other groups with interests in the Sierra, for example the National Astronomical Observatory, the guest ranches, the Kiliwa community, and researchers were generally supportive of the biosphere reserve initiative (Franco-Vizcaíno et al. 1996).

The relationship between our research group and the ranchers, which was tested during the confrontation over the logging road, has begun to strengthen and expand. They sought our support in soliciting the restoration of their logging permit, and we asked for their cooperation in a new research initiative to study the impacts of grazing on the meadow communities in the Sierra. This contact between researchers and land managers is a key component of "la modalidad mexicana" in biosphere reserves, because it provides a basis for better informing land-use decisions. Indeed, the management of recently established biosphere reserves in Mexico has been through coalitions ("grupos base") comprised of regional research institutions, non-governmental organizations, civic or private organizations (such as ejidal or tribal councils), and government agencies, each with a distinct responsibility but coordinated through a joint committee. While complicated, management through such a coalition ensures adequate representation of all parties while encompassing various areas of expertise and jurisdiction (Kaus 1996).

The implementation of the San Pedro Mártir Biosphere Reserve will require the establishment of such a coalition to assure the integration of the rural population with other groups working in the reserve. The coalition should have a governing board that represents the rural population, land managers, academics, and other interest groups such as the ecotourism industry. This board would be in charge of administering the biosphere reserve and would have the authority to charge fees

for hunting, camping, and ecotourism. It would also dispense funds and approve projects to support scientific research and maintenance of infrastructure. It is hoped that the non-governmental organization "Bosques de las Californias Asociación Civil" will be part of the coalition that will represent the interests of all parties and operate the reserve.

Structure and Management

The delimitation of core, buffer, and transition zones of a SSPM biosphere reserve will depend upon prospective resource goals agreed upon among the rural population, managers, and scientists. It is anticipated that a biosphere reserve in the Sierra will be defined by several of the resource values identified previously. The reserve borders should not modify the national park boundaries, nor the boundaries of the "Kiliwa reservation." Only the land-use activities within the national park and the reserve will need to be adjusted, in accordance with the management plan to be developed and administered by the coalition.

A land-use plan and attendant boundaries for a biosphere reserve must be mediated by those directly involved in the region, but the following discussion illustrates how a biosphere reserve that conserves resources and makes use of the grazing resource and existing infrastructure might be organized. The proposed reserve boundaries are shown in figure 2. This scenario has full consensus of our binational research team.

Core Zones

The biosphere "core" should probably be located along the eastern rim of Vallecitos and include the observatory, which requires strict control of land use and access in order to minimize dust and electromagnetic pollution. The core should be large enough to accommodate its defining activities. For example, the observatory complex is confined to the eastern edge of Vallecitos, but recreation needs will require improvement of the present campground, and development of a combined ecological and astronomical interpretive center in other portions of Vallecitos. The core may also include a research field station and perhaps a headquarters for government agencies responsible for the environment. For research purposes, the mixed conifer forest north of Vallecitos to Cerro Venado Blanco and Rancho Nuevo could also be included in the core. In our plan we defined the core as those lands in

the Sierra that are above 2,000 m in altitude and north of 31° latitude (see figure 2).

There are several reasons to have the core in this area:

1. A core designation protects the interests of the National Observatory.
2. Much of the formal research in the Sierra to date has taken place in the Vallecitos region.
3. The forests north of Vallecitos are among richest and most diverse mixed conifer forests in the Sierra, but have only small meadows.
4. The livestock industry would not be severely affected because the grazing resource in Vallecitos is minor compared to the more verdant meadows farther south.
5. Vallecitos has good access for maintenance of infrastructure.
6. Access facilitates recreation and education, as well as research objectives such as environmental monitoring.

A second core could be established in Kiliwa lands; this could include traditional use lands, and possibly an anthropology research laboratory located at the edge of the reserve near Valle Trinidad. The Kiliwa now survive in small numbers and are perilously close to vanishing. Every effort should be made protect the entire Kiliwa "reserve" to prevent external development from undermining the Kiliwa culture. A research program needs to be implemented to record Kiliwa culture, language, and their use of the land (Bendímez-Patterson 1991). There should also be an archaeological survey for sites in the Sierra; part of this survey should include the San Pedro Mártir mission site.

Buffer and Transition Zones

The designation of buffer and transition lands could make use of existing landownership. Buffer zones should include lands used seasonally for cattle grazing, and under protection of the national park, and areas set up for controlled hunting. These include the eastern and western escarpments, and grazed areas south of the Vallecitos plateau. Ejido lands might be placed within transition zones to promote their normal economic development.

In our plan we define the "buffer zone" as those lands above 500 m altitude on the eastern escarpment, and above 1,500 m on the western escarpment. To include Kiliwa lands in the northwest part of the re-

serve, the western border is extended from the 1,500 m contour 0.7 km south of the settlement of El Huico to El Huico, then follows a road from El Huico to La Cieneguita, then to Cañada La Parba and La Parra. From La Parra the border follows the western boundary of the Kiliwa Reserve northeastward to where it meets the 500 m contour.

Such a plan would protect the natural resources of the mountain, permit the continuation of seasonal cattle grazing, and allow economic development in lands immediately surrounding the Sierra. To protect the Sierra's resources highlighted in the following section, it will be necessary to restrict land use in the buffer zone. For each resource discussed, research topics are suggested that will require coordination between scientists, land managers, and the rural population.

LAND USE

Mission San Pedro Mártir de Verona

The mission site consists of adobe ruins, an extensive scatter of artifacts, some irrigation canals, and former cultivated fields. Unlike many other mission sites, the San Pedro Mártir mission has not been pillaged by looters or destroyed by urbanization. It consequently has the potential for economic benefit to the proposed biosphere reserve as an ecotourism site. The elevation of the mission site (1,600 m) places it within the buffer zone. Archaeological surveys of the mission site and other sites related to Dominican mission efforts, such as Casilepe, can be carried out in conjunction with surveys of prehistoric archaeology.

Livestock Grazing

Economic incentives and improved road facilities encourage overgrazing. The primary meadows occur within the national park, but although Mexican law does not permit grazing in national parks, cooperative arrangements have long existed between ranchers and the Ministry of Agriculture (SARH), which previously administered the park. On the other hand, biosphere reserves encourage the integration of conservation and rural development, so that a biosphere reserve may be an excellent mechanism to maintain sustainable grazing, supported by scientific research. Under the proposed biosphere reserve, meadows both within the national park and in the southern Sierra (Santa Rosa,

Santo Tomás, Santa Eulalia) would come under a buffer zone status. This would be done to maintain the present system of seasonal cattle grazing.

Cooperative arrangements can be refined for the purposes of a biosphere reserve. This will also require that land managers and scientists consider the views of cattle ranchers concerning the pastoral resource. Ranchers can also play the role of informed caretakers of the Sierra by expanding their guardianship activities within the biosphere reserve framework. More research will be required to establish the relationship between the intensity of cattle grazing and degradation of the meadows. We believe that much of the Sierra's plateau (including the meadows and routes of the seasonal cattle drives) should be placed in the buffer zone, because meadows are so resilient and the chaparral and forests are little used by the animals. Meadows outside the park, such as Santa Rosa and those of Santa Eulalia should also be placed in the buffer zone to prevent overgrazing in these areas.

Continued research on cattle impacts will require long-term monitoring of the effect of grazing on meadow biomass and species composition through exclosure studies. In addition to our baseline study at Vallecitos, new exclosures should be established at the primary meadows in the central and southern Sierra. New studies could utilize existing exclosures (such as those of COTECOCA) and preexisting fencing. Other issues that should be addressed are the impacts of livestock on soil, groundwater, and stream nitrification. Some megafauna, such as deer, may also lose habitat because of cattle grazing.

Mixed Conifer Forest, Chaparral, and Fire Suppression

The Sierra's Californian mixed conifer forests grow above 1,800 m and nearly all stands would be placed in either core or buffer zones. The San Pedro Mártir biosphere reserve would serve as a showcase for research in fire ecology for similar ecosystems throughout the southwestern United States and northwestern Mexico. Furthermore, an unmanaged fire regime will result in forests and chaparral that require much less funding to manage, and in the end are less threatening to the livestock industry, life, and property.

The research team strongly recommends that biosphere reserve management not adopt the outmoded fire-suppression policies of industrialized countries. Fire control should be strictly limited to areas

surrounding the telescopes, structures, and important resources. Fires should be allowed to run their course in the remainder of the Sierra. Periodic fires have been part of these forest ecosystems for millennia and are important to forest structuring and natural cycling processes.

As a natural fire laboratory, the Sierra will permit research in fire ecology that is not possible in industrialized countries, where fire control has already modified fire regimes and vegetation for nearly a century. In those countries, research in fire ecology has been retrospective, through examination of historical literature and methods such as tree-ring fire chronologies and stand age-class reconstructions. In the Sierra, unmanaged fire regimes can be examined and can include studies on fire behavior, vegetation damage, burn patch dynamics, long-term monitoring of post-fire succession, and other fire-related phenomena. The isolation of the Sierra's forests may also yield valuable information on forest genetics.

The Sierra's mixed conifer forests also require protection because they are unique to Mexico in species composition. Moreover, their isolation from the nearest forests in California (300 km north) may have contributed to genetic differentiation of several trees and shrubs. *Abies concolor* in the Sierra, for example, have abnormally thick needles (Vasek 1985). Tom Ledig (personal communication) states there is more genetic variation in *Pinus coulteri* among the rare populations of northern Baja California than among the extensive forests in California. The montane chaparral species *Arctostaphylos patula* and *Ceanothus cordulatus* in the Sierra grow to as tall as 2 to 3 m, while in California forests they are normally prostrate at less than 1.5 m in stature. *Quercus chrysolepis* has small leaves and is shrubby compared to California populations (Myatt 1975).

WILDLIFE MANAGEMENT

Game Species

Game species such as the mountain sheep and quail could be a valuable potential resource for the proposed biosphere reserve. For this reason, the present policy of complete prohibition of hunting (Mellink-Bijtel 1993) should be reconsidered. Sport hunting may help to regulate populations, and provide a financial resource to sustain the scientific objectives and management of the biosphere reserve.

The Sierra's eastern escarpment supports the largest homogeneous population of the peninsular race of mountain sheep. At present hunting of mountain sheep is under moratorium (Mellink-Bijtel 1993) until a survey by the Mountain Sheep Institute in Ensenada is completed. Liaison with the institute will be required, and policies should reflect the census data compiled and conservation priorities outlined by the institute.

If permit hunting is implemented in the future, the moneys obtained should be allocated for wildlife management in Baja California. The lucrative moneys generated by sheep tags will also require strict permitting procedures under federal control. Hunters should be escorted by land managers. Hunting must be paralleled by the development of scientific databases on sheep numbers, gender distribution, foraging characteristics, and other parameters. Knowledge of short-term population dynamics will be necessary to estimate the number of hunting permits. Sheep should be placed in a "buffer zone" status to ensure tight regulation, even though most habitat is nearly inaccessible. This is accomplished by defining the eastern boundary of the biosphere reserve as the 500 m contour.

Hunting may be a mechanism to integrate the ejidos east of the Sierra into the activities of a biosphere reserve. Another source of income for eastside ranches may be a permit or guide system for mountain/rock climbing in the precipices of the eastern escarpment, such as Picacho del Diablo. Potential research topics on mountain sheep ecology would include population dynamics, migratory habits and diet (especially of endemic plants), plant-animal relations, and interactions with feral burros, deer, and other megafauna. Understanding how to effectively manage the population is essential because controlled licensed hunting may be allowed in the future.

Rainbow Trout

Buffer zone land-use restrictions will be necessary to protect the few populations of the rainbow trout from overfishing. This unique warm-water trout, likely the purest remaining form of *Onchorhynchus mykiss* due to its long isolation from other stocks, is listed as a "species of special concern" by the American Fisheries Society, and as "rare" by the Ministry of Environment (SEMARNAP). Its habitat is also threatened by increased livestock grazing and other changes in land-use practices

(Ruiz-Campos, Pister, and Compean-Jimenez 1995). For example, extensive blooms of potentially toxic cyanobacteria have been noted in the Río Santo Domingo below La Grulla meadow. This eutrophication likely results from nutrient loading by cattle wastes as the stream crosses the heavily grazed meadow. Many native fish species in southern California, also living in marginal streams, were quickly fished to extinction before protective measures could be established. Under the proposed biosphere boundaries, most populations in Arroyos San Antonio and San Rafael are protected.

Research should be done to evaluate how to manage this population sustainably with respect to stream sedimentation and eutrophication due to grazing. Studies on trout ecology should be continued, and new studies should be initiated on habitat improvement and the effects on population dynamics of stream fluctuations by stream floods and drought. Efforts should be made to transplant trout to other streams, and to prevent the introduction of other fish species that could compete with this endemic subspecies.

Protection of Endemic or Rare Plant Species

The Sierra has several plant species that are rare or endemic to it. ***Cupressus montana*** and several forbs receive natural protection because their distributions are restricted to the precipitous eastern escarpment. Conversely, several others are confined to meadow habitats subject to grazing. In our exclosure studies we found that some endemics, such as ***Ophiocephalus angustifolius,*** thrive with grazing disturbance. However, our knowledge of most rare or endemic species is limited. Hence, the implementation of a sustainable management system for these species will require formal research on the ecology of these endemics and their adaptation to land-use disturbances. Potential research would include studies on the genetics, ecology, habitat, and population characteristics of endemic species. Little is known regarding the foraging by mountain sheep on endemic or other browse species on the eastern escarpment.

Reintroduction of the California Condor

An excellent and timely issue for the establishment of a biosphere reserve would be cooperative conservation efforts among the govern-

ments of California and Baja California toward the restoration of the magnificent California condor to the Sierra. The success of captive breeding programs at San Diego and Los Angeles zoos now presents an opportunity to release birds into favorable habitats, such as the Sierra. The study team believes that the condor has a good chance for successful renaturalization in the Sierra. The Sierra's eastern escarpment contains abundant cliff faces and ledges favorable to their roosting and nesting. Updrafts associated with the high relief are also favorable for soaring. Chaparral and other plant ecosystems have diverse patch structure, which is favorable for a plentiful food resource base for the bird, and burned patches provide sites for easy takeoffs and landings. The U.S. Fish and Wildlife Service is currently investigating the possibility of developing a release project in the Sierra as part of the initiative to establish the San Pedro Mártir biosphere reserve (Mesta 1996).

The reintroduction of the California condor to the Sierra may serve both as a focal rallying point toward a biosphere reserve by local populations and land managers and as a management centerpiece for the establishment of a biosphere reserve, because such an effort would bring international attention and require the integration of sustainable management of other natural resources. For example, limited fire control to maintain fine-grained chaparral patch structure and open forest structure may be necessary in order to optimize habitat for the bird. Livestock grazing adds a carrion resource. Unlike other vultures, condors apparently do not expel bone and other solid materials; this makes them especially susceptible to lead poisoning from the ingestion of bullets in carrion (R. Mesta, personal communication).

The reintroduction of condors may thus require strict controls on escorted trophy hunting of mountain sheep to prevent lead poisoning, and will require coordination with neighboring ranches to minimize use of toxic materials. The reintroduction of condors, of course, will require coordinated efforts with research institutions in the United States committed to the breeding and release of California condors. Potential research studies could focus on naturalization of released birds, home range and distribution of activity, condor population ecology and diet preference, adaptation of condors to natural disturbance, and human-condor interactions.

CONCLUSION

As a biosphere reserve, the Sierra San Pedro Mártir can serve as an extraordinary resource for a number of purposes beneficial to Mexico and the international community. A biosphere reserve will help conserve a region of striking diversity and geographic isolation that includes many rare and endemic species. The Sierra San Pedro Mártir can also serve as an extraordinary "showcase" of ecosystems functioning with natural disturbance processes at the landscape scale and under a traditional management system for comparison with similar temperate ecosystems under other management elsewhere. The Sierra also hosts a grazing economy preserved from the nineteenth century and a small Indian population. The habitat is also suitable for an experiment of international importance: the reintroduction of the California condor.

There is already historical precedent for the protection of the Sierra through the establishment of the Sierra San Pedro Mártir National Forest Reserve and National Park. Scientific expertise exists in terrestrial ecology, anthropology, and related subjects, as well as the research infrastructure of the National Observatory. This scientific expertise can be tapped for the development of the proposed biosphere reserve's education and training function. Tour visits to the observatory, trout streams, and San Pedro Mártir archaeological site; rock climbing on Picacho del Diablo; condor watching; and other activities will foster an increased sense of stewardship by the local population over the historic, archaeological, ecological, and other sites within the biosphere reserve.

Our multidisciplinary research group has developed a baseline database that resulted from studies in climatology, hydrology, ecology, fire history, grazing impacts, and archaeology from which a larger body of research can arise to help reconcile land use with biological conservation. A biosphere reserve management plan could keep most aspects of the current economy and land use. Thus, the transition to a biosphere reserve can be readily undertaken without undermining the activities of the rural population. ✣

Table 1. Common species of selected plant communities in northwestern Baja California.

Species	Common Name[1]
CHAPARRAL	
Shrubs	
Adenostoma fasciculatum	chamise (chamiso, vara prieta)
A. sparsifolium	redshank (chamiso de vara colorada)
Arctostaphylos glauca	bigberry manzanita (manzanita)
A. peninsularis	peninsular manzanita (manzanita peninsular, manzanita)
Ceanothus cuneatus	lilac, ceanothus (bracillo)
C. greggii	desert ceanothus (bracillo)
C. leucodermis	chaparral whitehorn, ceanothus (bracillo)
Juniperus californica	California juniper (junípero, huata, cedro, ciprés)
Nolina parryi	nolina (sotol, palmita)
Pinus quadrifolia	Parry pinyon (piñón de cuatro agujas, piñón)
P. coulteri	Coulter pine (pino Coulter)
Platanus racemosa	western sycamore (sicámoro del oeste, aliso)
Populus fremontii	Fremont cottonwood (álamo)
Quercus agrifolia	coast live oak (encino)
Q. cornellius-mulleri	desert scrub oak (encinillo, encinito chaparro)
Q. chrysolepis	canyon live oak (encino del cañón, encino)
Q. dumosa	scrub oak (encinillo, encinito chaparro)
Rhus ovata	sugarbush sumac (lentisco)
Yucca schidigera	Mojave yucca (palmilla, dátil)
PINYON FOREST	
Trees	
Juniperus californica	California juniper (junipero, huata, cedro, ciprés)
Pinus monophylla	singleleaf pinyon (piñón)
P. quadrifolia	Parry pinyon (piñón de cuatro agujas, piñón)
Shrubs	
Arctostaphylos peninsularis	peninsular manzanita (manzanita peninsular, manzanita)
Cercocarpus betuloides	birch-leaf mountain mahogany (hoja de abedul, caoba de montaña)
Garrya grisea	silktassle bush
Nolina parryi	nolina (sotol, palmita)
Prunus ilicifolia	hollyleaf cherry (hoja santa, cereza)

Q. cornellius-mulleri	desert scrub oak (encinillo, encinito chaparro)
Rhus kearneyi	desert sumac (lentisco)
R. ovata	sugarbush sumac (lentisco)
Yucca schidigera	Mohave yucca (palmilla, dátil)

MIXED CONIFER FOREST

Trees

Abies concolor	white fir (abeto blanco, abeto, pino blanco)
Calocedrus decurrens	incense cedar (cedro incienso, ciprés)
Cupressus montana	mountain cypress (ciprés de montaña, ciprés)
Pinus contorta	lodgepole pine (pino)
P. jeffreyi	Jeffrey pine (pino)
P. lambertiana	sugar pine (pino)
Populus tremuloides	quaking aspen (alamillo, álamo)
Quercus chrysolepis	canyon live oak (encino del cañón)
Q. peninsularis	Pacific Emory oak (Encinillo)

Shrubs

Arctostaphylos patula	green-leaf manzanita (manzanita)
A. pringlei	pinkbract manzanita (manzanita)
A. pungens	Mexican manzanita (manzanita mexicana)
Artemisia tridentata	Great Basin sagebrush (chamiso blanco)
Ceanothus cordulatus	(snowbush ceanothus) bracillo
Garrya grisea	silktassle
Rhamnus californica	coffeeberry (yerba de oso)
Salvia pachyphylla	rose sage (salvia rosa)
Symphoricarpos parishii	snowberry

MICROPHYLLOUS WOODLAND/CREOSOTE BUSH SCRUB/ CENTRAL DESERT SCRUB

Acacia greggii	catclaw (uña de gato)
Agave desertii	desert agave (agave, mescal, maguey)
Ambrosia dumosa	white bursage (huizapol)
Cercidium floridum	blue paloverde (palo verde)
Echinocereus engelmannii	hedgehog cactus (pitayita)
Encelia farinosa	brittlebush (incienso)
Fouqueria columnaris	boojum tree (cirio)
F. splendens	ocotillo (ocotillo)
Larrea tridentata	creosote bush (gobernadora)
Opuntia acanthocarpa	buckhorn cholla (cholla)

O. basilaris	beaver-tail cactus (nopal, tuna)
O. echinocarpa	silver cholla (cholla)
Olneya tesota	desert ironwood (palo fierro)
Pachycereus pringlei	cardon (cardón)
Prosopis glandulosa	honey mesquite (mezquite)
Stenocereus thurberi	organ pipe cactus (pitahaya dulce)

PALM OASIS

Brahea armata	blue fan palm (Palma ceniza, palma)
Prosopis glandulosa	(honey mesquite) mezquite
Salix spp.	willow (sauce)

[1]Spanish common names after Moran (1977), Roberts (1989), Tiscareño and Robinson (1969), and Martínez (1947).

Table 2: Characteristic Mammals of the Sierra San Pedro Mártir[1].

Species	Common Name
CHAPARRAL ZONE	
Ammospermophilus leucurus	ground squirrel (ardilla)
Dipodomys merriami	Merriam's kangaroo rat (rata kanguro de Merriam)
Lepus californicus	black-tailed jackrabbit (liebre cola negra)
Mephitis mephitis	striped skunk (zorillo)
Neotoma fuscipes	dusky-footed woodrat (rata)
N. lepida	desert woodrat (rata)
Onychomys torridus	southern grasshopper mouse (ratón)
Perognathus californica	pocket mouse (ratón)
P. fallax	San Diego pocket mouse (ratón San Diego)
P. longimembris	pocket mouse (ratón)
Peromyscus californicus	California mouse (ratón California)
P. eremicus	cactus mouse (ratón de cactus)
P. maniculatus	deer mouse (ratón)
Procyon lotor	raccoon (mapache)
Reithrodontomys megalotis	western harvest mouse (ratón)
Sorex californicus	California shrew (musaraña Californiana)
S. ornatus	ornate shrew (musaraña)
Sylvilagus audiboni	Audubon cottontail (conejo Audubon)
S. bachmani	Bachman's Audubon cottontail (conejo matorralero)
Taxidea taxus	badger (tejón)
Thomomys bottae	pocket gopher (topo)
T. umbrinus[2]	pocket gopher (tuza)
MIXED CONIFER FOREST ZONE	
Chaetodipus californicus[3]	California pocket mouse (ratón)
Eptesicus fuscus	big brown bat (murcielago café)
Eutamias obscurus[3]	Merriam chipmunk (chichimoco)
Microtus californicus[2]	California vole (ratón Californiano)
Myotis evotis	long-eared bat (murcielago orejas largas)
M. milleri[2]	myotis bat (murcielago)
M. orinomus	myotis bat (murcielago)
Myotis subulatus	myotis bat (murcielago)
M. yumanensis	Yuma myotis (murcielago
Neotoma fuscipes	dusky-footed woodrat (rata pata oscura)
N. lepida	woodrat (rata)
Peromyscus boylii	brush mouse (ratón)

P. maniculatus	deer mouse (ratón)
P. truei[3]	pinyon mouse (ratón piñonero)
Pipistrellus hesperus	western pipiestrelle (murcielago)
Scapanus latimanus[2]	broad-footed mole (topo)
Spermophilus beecheyi	(Beechy ground squirrel) ardilla de tierra
Spilogale putorius	skunk (zorrillo)
Tadarida brasiliensis	Brazilian free-tailed bat (murcielago)
T. femorasacca	free-tailed bat (murcielago)
Tamiasciurus mearnsii[2]	Douglass squirrel, SSPM chickaree (ardilla)
MEGAFAUNA	
Bassariscus astulus	ringtail (babísuri)
Canis latrans	coyote (coyote)
Felis concolor	mountain lion, cougar (puma)
Lynx rufus	bobcat (gato montés)
Odocoileus hemionus	mule deer (venado)
Ovis canadensis cremnobates	mountain bighorn sheep (borrego cimarrón)
Urocyon cinereoargenteus	gray fox (zorra gris)

[1]From Nelson (1921); Bond (1977); Mellink-Bijtel (1991).
[2]Species endemic to SSPM
[3]Subspecies endemic to SSPM.

Table 3: Characteristic Birds of the Sierra San Pedro Mártir.

Species	Common Name
CHAPARRAL ZONE	
Agelaius phoeniceus	red-winged blackbird (mirlo ala roja)
Aimophila ruficeps[1]	rofous-crowned sparrow (gorrión)
Amphispiza belli	sage sparrow (chiero de lunar)
Aphelocoma coerulescens[1]	scrub jay (grajo de chaparral)
Archilochus alexandri	black-chinned hummingbird (chupaflor)
Ardea herodias	great blue heron (garza azul, garza morena)
Asio otus	long-eared owl (lechuza barranquera)
Bombycilla cedorum	cedar waxwing (chinito picotero)
Callipepla californica[1]	California quail (codorniz)
Calypte anna	Anna's hummingbird (chupaflor cuello escarlata)
Carduelis lawrencei	Lawrence's goldfinch (gorrión)
C. psaltria	lesser goldfinch (gorrión)
Carpodacus mexicanus	house finch (gorrión común)
Catharus guttatus	hermit thrush (mirlillo solitario)
Chamea fasciata[1]	wren tit (reyezuelo, camea)
Charadrius vociferus	killdeer (tildio, chorlito)
Chordeiles accutippenis	lesser nighthawk (tapacamino, halcón)
Eremophila alpestris	horned lark (calandria)
Euphagus cyanocephalus	Brewer's blackbird (mirlo de Brewer)
Icterus cucullatus	hooded oriole (calandria zapotera)
Lanius ludovicianus[1]	loggerhead shrike (verduguillo, cabezón)
Loxia curvirostra	red crossbill (picocruzado)
Melospiza melodia	song sparrow (gorrión)
Myadestes townsendi	Townsend's solitaire (jilguero norteño)
Myarchus cinerascens	ash-throated flycatcher (copetón cenizo)
Otus kennicotti	western screech-owl (tecolotillo chillón)
Parus inornatus[1]	plain titmouse (paro)
Passerculus sandwichensis	Savannah sparrow (gorrión)
Passerela iliaca	fox sparrow (gorrion vulpino)
Passerina amoena	lazuli bunting (verderón)
Phalaenoptilus nuttallii	common poorwill (pachuca común)
Pheuctitus melanocephalus	black-head grosbeak (tigrillo)
Pipilo erythrophthalmus	rufous-sided towhee (toquí de socorro chowis)
P. fuscus[1]	brown towhee (carcachil café, vieja)
Polioptila californica[1]	California gnatcatcher
Psaltriparus minimus[1]	bushtit (sastre, sastrecito)
Pyrocephalus rubinus	vermilion flycatcher (brasita de fuego)
Regulus calendula	ruby-crowned kinglet (reyezuelo de rojo)
Sayornis nigricans[1]	black phoebe (mosquero [o papamoscas] negro)
S. saya[1]	Say's phoebe (mosquero Say)
Sialia mexicana[1]	western bluebird (ventura azul)

Sphyrapicus ruber	red-breasted sapsucker (carpintero saucero)
Sturnella neglecta	western meadowlark (calandria de prado)
Thryomanes bewickii[1]	bewick's wren (gorrión)
Toxostoma cinereum[1]	gray thrasher (cuitlacoche ceniciento)
T. dorsale[1]	Crissal thrasher (sisnote Crissal)
T. redivivum	California thrasher (sisnote California, cuitlacoche)
Tyrannus verticalis	western kingbird (tirano, muscícapa)
Vireo bellii	Bell's vireo (vireo de Bell)
V. vicinior	gray vireo (vireo)
Wilsonia pusilla	Wilson's warbler (pelucilla)

MIXED CONIFER FOREST ZONE

Accipiter striatus	sharp-shinned hawk (gavilán pajarero)
Carduelis pinus	pine siskin (verderón)
Carpodacus cassini	Cassin's finch (gorrión de Cassin)
Colaptes cafer auratus[1]	northern flicker (carpintero alirojo)
Columba fasciata	band-tailed pigeon (paloma)
Contopus borealis	olive-sided flycatcher (mosquerito)
Dendroica coronata	yellow-rumped warbler (gusanero cabecigris)
Empidonax difficilis	western flycatcher (mosquerito barranquero)
Gymnorhinus cyanocephalus	pinyon jay (urraca piñonera, queisque piñonero)
Junco hyemalis[1]	black-eyed junco (carbonero oregonense)
Melanerpes formicivorus[1]	acorn woodpecker (carpintero encinero)
Nucifraga columbiana	Clark's nutcracker (cascanueces de Clark)
Oreortyx pictus[1]	mountain quail (codorniz de montaña)
Parus gambeli[1]	mountain chickadee (paro carbonero)
Picoides nuttallii	Nuttall's woodpecker (carpintero de Nuttall)
P. villosus	hairy woodpecker (pájaro carpintero)
Piranga ludoviciana	western tanager (tángara)
Progne subis	purple martin (golondrina)
Sitta carolinensis[1]	white-breasted nuthatch (saltapared, trepatroncos)
S. pygmaea[1]	saltapared enano trepatroncos (pygmy nuthatch)
Sphyrapicus thyroideus	carpintero de Williamson (Williamson's sapsucker)
Stellula calliope	chupaflor (calliope hummingbird)
Strix occidentalis	spotted owl (buho manchado)
Tachycineta thalassina	violet-green swallow (golondrina verde)
Troglodytes aedon	house wren (reyezuelo casero)
Vireo solitarius	solitary vireo (vireo solitario)

[1]Nelson (1921); Kratter (1991, 1992); American Union of Ornithologists (1983); Rodriguez-Meraz (1991).

Table 4. Rare and/or endemic plants of the Sierra San Pedro Mártir.

Species	Habitat
Agave moranii[1]	lower E escarpment and bajadas
Astragalus circumdatus	open, sandy places, also Sierra Juárez
A. gruinus	sandy soils, margins of meadows
Cercocarpus ledifolius	Single population E. of the Observatory
Cupressus montana[1]	rocky slopes and arroyos, E escarpment, La Encantada
Draba corrugata[1]	rocky, gravelly slopes in pine forest
Eriogonum hastatum	sandy areas, also Sierra Juárez
Galium wigginsii[1]	granite boulders
G. diabloense[1]	sandy arroyos and rocky places on Picacho del Diablo
Garrya grisea	weathered granite slopes
Haplopappus wigginsii[1]	high meadows, sandy gravelly flats
H. martirensis[1]	weathered granite, crevices, ridges
H. pulvinatus[1]	very rare; high E cliffs, P. del Diablo and Cerro Observatorio
Hedeoma martirense[1]	high E rim
Heterotheca martirensis[1]	rock outcrops, E rim
Lesquerella peninsularis	sandy meadows
Mimulus exiguus	wet sand, also Sierra Juárez and San Bernardino Mountains
M. purpureus pauxillus	meadows and washes
Ophiocephalus angustifolius[1]	meadows
Pinus coulteri	N of Cerro Venado Blanco and W of Sta. Eulalia
Rhus kearneyii	washes, E escarpment
Sedum niveum	rocky places, high E rim; mountains of SE California
Senecio martinensis[1]	margins of meadows and rocky slopes
Sphaeralcea martirense[1]	High E rim
Sphaeromeria martirensis	frequent on E rim
Stephanomeria monocephala[1]	high E rim
Trifolium wigginsii[1]	high meadows; open, moist, gravelly areas

Source: After: Moran (1977); Wiggins (1980); R. F. Thorne, personal communication.
[1]Endemic species.

Table 5. Spatial extent of vegetation types of the Sierra San Pedro Mártir.

Vegetation Type[1]	Area (ha)	Dominant Species
CONIFER FORESTS		
Jeffrey pine	19,557	*Pinus jeffreyi*
mixed Jeffrey pine	15,378	*P. jeffreyi, Abies concolor*
mixed pine/cypress	56	*P. jeffreyi, Cupressus montana*
mixed incense cedar	554	*Calocedrus decurrens, P. jeffreyi*
mixed white fir	3,400	*Abies concolor, P. lambertiana*
mixed cypress	617	*C. montana, P. lambertiana, A. concolor*
mountain cypress	123	*C. montana*
mixed lodgepole pine	970	*P. contorta, P. jeffreyi*
Coulter pine	156	*P. coulteri*
cypress/4-needle pinyon	1,171	*C. montana, P. quadrifolia*
4-needle pinyon	10,532	*P. quadrifolia*
single-leaf pinyon	12,092	*P. monophylla*
BROAD-LEAF FOREST		
coast live oak	542	*Quercus agrifolia*
canyon live oak	19,617	*Q. chrysolepis*
Pacific Emory oak	6,033	*Q. peninsularis*
quaking aspen	465	*Populus tremuloides*
SHRUBLAND AND HERBACEOUS COMMUNITIES		
chamise chaparral	53,977	*Adenostoma fasciculatum, Ceanothus greggii*
redshank chaparral	16,857	*A. sparsifolium, A. fasciculatum*
mixed chaparral	195	*Q.wislizenii, Q.dumosa, C. leucodermis*
ceanothus chaparral	129	*C. oliganthus, C. verrucosus*
peninsula chaparral	24,298	*Arctostaphylos peninularis*
manzanita chaparral	13,478	*A. pringlei, A. pungens*
timberland chaparral	21,192	*A. patula, C. cordulatus*
mahogany chaparral	43	*Cercocarpus ledifolius*
Great Basin sagescrub	540	*Artemisia tridentata*
coastal sagescrub	4,851	*Eriogonum fasciculatum, Salvia apiana*
mountain meadow	2,588	*Juncus* spp., *Carex* spp.
creosote bush scrub	32,710	*Larrea tridentata, Ambrosia dumosa*
microphyllous woodland	13,656	*Olneya tesota, Cercidium floridum, Psorothamnus spinosus*

[1]Calculated from the GIS.

APPENDIX

Institutions Involved in Research or Management of the Sierra San Pedro Mártir

Asociación Ganadera de San Telmo/San Telmo Cattle Ranchers' Association

Centro de Investigación Científica y de Educaciøn Superior de Ensenada (CICESE)/Center for Scientific Research and Higher Education of Ensenada

Colegio de la Frontera Norte (COLEF)/College of the Northern Border

Comisión Nacional del Agua/National Water Commission

Comité para el Desarollo Económico de San Quintín (CODEREQ)/Committee for the Economic Development of San Quintín

Consejo de los Peces del Desierto/Desert Fishes Council

Instituto Nacional de Antropología e Historia (INAH)/National Institute for Anthropology and History

Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)/National Institute for Forestry, Agricultural and Animal Husbandry Research

Oficina del Parque Nacional San Pedro Mártir/Office of the San Pedro Mártir National Park

Secretaría de Asentamientos Humanos y Obras Públicas del Estado de BC (SAHOPE)/Ministry of Housing and Public Works of the State of Baja California

Secretaría del Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP)/Ministry of the Environment, Natural Resources and Fisheries

Secretaría de Fomento Agropecuario del Estado de Baja California/Ministry for Promotion of Agriculture of Baja California

Secretaría de Desarollo Económico del Estado de Baja California/Ministry for Economic Development of Baja California

Universidad de California (Davis, Riverside)/University of California (Davis, Riverside)

Universidad Estatal de California (Fullerton, Monterey Bay, San Diego)/ California State University (Fullerton, Monterey Bay, San Diego)

Universidad Autónoma de Baja California/Autonomous University of Baja California

Escuela de Ciéncias Biológicas (Ensenada)/School of Biological Sciences (Ensenada)

Instituto de Investigaciones Sociales (Mexicali)/Institute for Social Research (Mexicali)

Instituto del Borrego Cimarrón/Institute for Mountain Sheep

Universidad Nacional Autónoma de México (UNAM)/ National Autonomous University of Mexico

Observatorio Astronómico Nacional/National Astronomical Observatory

LITERATURE CITED

Aguilar-Rodríguez, J. L. 1991. Perspectivas de conservación del borrego cimarrón en Baja California. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 38. Ensenada: CICESE.

Alvarez, M. 1981. *Aspectos climáticos del Observatario Astronómico Nacional: Reporte de año de 1969.* Instituto de Astronomía, Reporte No. 5, Universidad Nacional Autónoma de México.

Alvarez, M., and Maisterrena, J. 1977. Climatological and meteorological characteristics of the Observatorio Nacional at San Pedro Mártir, B.C. *Revista Mexicana de Astronomía y Astrofisica* 2:43–52.

Barbour, M. G. 1988. Californian upland forests and woodlands. In *North American Terrestrial Vegetation,* ed. M. G. Barbour and W. D. Billings, 131–64. New York: Cambridge University Press.

Barbour, M. G., and Minnich, R. A. In press. Californian upland forests and woodlands. In *North American Terrestrial Vegetation,* ed. M. G. Barbour and W. D. Billings. 2d. ed. New York: Cambridge University Press.

Barrett, E. C. 1957. *Baja California 1535–1956.* Los Angeles: Bennett and Marshall.

Barry, W. J. 1991. *The potential for a transborder biosphere reserve representing the Peninsular Range ecological region of Baja and Alta Californias.* Cabo San Lucas: Commission of the Californias, 46th General Assembly.

Bendímez-Patterson, J. 1991. Recopilación de información antropológica en la zona de San Pedro Mártir como parte del proyecto para la reserva de la biosfera. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 29–30. Ensenada: CICESE.

Bolton, H. E. 1927. *Fray Juan Crespi: Missionary Explorer on the Pacific Coast, 1769–1774.* Berkeley: University of California Press.

Bond, S. I. 1977. An annotated list of the mammals of San Diego County, California. *Transactions of the San Diego Society of Natural History* 18:229–47.

Brown, D.E. 1992. Arizona's pronghorn challenge. *Defenders* Mar/Apr: 24–31.

Brown, J. W. 1987. The peninsular effect in Baja California: An entomological assessment. *Journal of Biogeography* 14:359–65.

Burk, J. H. 1991. Conifer forest fire history of the Sierra San Pedro Mártir. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 25. Ensenada: CICESE.

Burrus, E. J. 1966. *Wenceslaus Linck's Diary of his 1766 Expedition to Northern Baja California.* Los Angeles: Dawson's Book Shop.

Chambers, K. L. 1955. A collection of plants from the eastern flank of the Sierra San Pedro Mártir. *Contributions to the Dudley Herbarium* 4:323–30.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud, and D. Williams. 1983. *Fire in Forestry.* 2 Vols. New York: John Wiley and Sons.

Cody, M. L., R. Moran, and H. Thompson. 1983. The plants. In *Island Biogeography in the Sea of Cortez,* ed. T. J. Case and M. L. Cody, 49–97. Berkeley: University of California Press.

Cottam, G., and D. T. Curtis. 1956. The use of distance measurements in phytosociological sampling. *Ecology* 37:451–60.

Escoto-Rodríguez, M. 1994. Balance del agua del suelo en trés sitios de estudio en la Sierra de San Pedro Mártir, Baja California. Licentiate thesis, Universidad Autónoma de Baja California, Ensenada.

Foster, J. W. 1991. The Mission San Pedro Mártir de Verona: A brief history and assessment of interpretative potential within a biosphere reserve. In *Evaluation of the Feasibility of a Transborder Biosphere Reserve,* CICESE Technical Report CIEC59101. Ensenada: CICESE. (English and Spanish)

———. 1992. La Grulla: An archaeological survey of a high mountain meadow in the Sierra San Pedro Mártir, Baja California, Paper presented to the 26th annual meeting of the Society for California Archaeology, Pasadena (Abstract).

Franco-Vizcaíno, E., H. de la Cueva, and C. Montes (ed.). 1996. *Strategies for Conservation of the Sierra San Pedro Mártir.* Abstracts of the International Conference held at Ensenada 4–5 December 1995. Ensenada: CICESE. (English and Spanish)

Franco-Vizcaíno, E., and J. Sosa-Ramírez (eds). 1991. *The Potential for the Peninsular Range of the Californias as a Biosphere Reserve.* Memoirs of the International Conference held at Ensenada, 18–19 March 1991, CICESE Technical Report CIEC09101. Ensenada: CICESE. (English and Spanish)

Franco-Vizcaíno, E., J. Sosa-Ramírez, R. A. Minnich, and M. G. Barbour. 1992. *Nutrient Concentrations in soils and Tissues of Shrublands and Meadows of Alta and Baja California.* CICESE Technical Report CIEC9202. Ensenada: CICESE.

Freedman, J. R. 1984. Uncontrolled fire and chaparral resilience in the Sierra Juárez, Baja California. M.S. thesis, University of California, Riverside.

Gastil, R. G., R. P. Phillips, and E. C. Allison. 1975. *Reconnaissance Geology of the State of Baja California.* Geological Society of America Memoir 140. Boulder: Geological Society of America.

Goldman, E. A. 1916. Plant records of an expedition to Lower California. *Contributions to the U.S. National Herbarium* 16:309–371.

Gómez-Pompa, A., and R. Dirzo (tech. coords.). 1994. Proyecto sobre áreas protegidas de México. Anexo 1, Areas protegidas establecidas, report to the Secretary of Social Development.

Gómez-Pompa, A., and A. Kaus. 1992. Taming the wilderness myth: environmental policy and education are currently based on western beliefs about nature rather than on reality. *Bioscience* 42:271–279.

Grinnell, J. 1928. A distributional summation of the ornithology of Lower California. *University of California Publications in Zoology* 32:1–300.

Halffter, G. 1981. The Mapimi Biosphere Reserve: Local participation in conservation and development. *Ambio* 10:93–96.

Henderson, D. A. 1960. Geography of the Sierras Juárez and San Pedro Mártir, Baja California, Mexico. *The California Geographer* 1:21–28.

———. 1964. Agriculture and Stock Raising in Baja California. Ph.D. diss., University of California, Los Angeles.

Hinton, T. B., and R. C. Owen. 1957. Some surviving Yuman groups in northern Baja California. *América Indígena* 17:87–102.

Instituto Nacional de Estadística, Geografía, e Informática. 1983. *X censo general de población y vivienda, 1980, estado de Baja California*. Vol. 1., Tomo 2, México, D.F.: Estados Unidos Mexicanos, Secretaría de Programación y Presupuesto.

Johnson, E. A., and S. L. Gutsell. 1994. Fire frequency models, methods and interpretations. *Advances in Ecological Research* 15: 239–87.

Kaus, A. 1996. Biosphere reserves and the Mexican modality. In *Strategies for Conservation of the Sierra San Pedro Mártir*, ed. E. Franco-Vizcaíno, H. de la Cueva, and C. Montes, 1–3. Ensenada: CICESE.

Koford, C. B. 1953. *The California Condor.* New York: National Audubon Society.

Kratter, A. W. 1991. First nesting record for Williamson sapsucker (*Sphyrapicus thyroideus*) in Baja California, Mexico, and comments on the biogeography of the fauna of the Sierra San Pedro Mártir. *Southwestern Naturalist* 36:247–50.

———. 1992. Montane avian biogeography in southern California and Baja California. *Journal of Biogeography* 19:269–83.

Markham, C. B. 1972. Baja California's climate. *Weatherwise* 25:64–76.

McKelvey, K. S., and J. D. Johnston. 1992. Historical perspective on forests of the Sierra Nevada and the Transverse Ranges of southern California: Forest conditions at the turn of the century. In *The California Spotted Owl: A Technical Assessment of Its Current Status,* tech. coords. J. Verner, K. S. McKelvey, B. R. Noon, R. J. Gutiérrez, G. I. Gould, and T. W. Beck. 225–46. U.S. Forest Service General Technical Report PSW-GTR-133. Washington, D.C.: Government Printing Office.

Meigs, P. 1935. The Dominican mission frontier of Lower California. *University of California Publications in Geography* 7:1–232.

———. 1939. The Kiliwa Indians of Lower California. *Ibero-Americana* 15.

Meling-Pompa, D. 1991a. La ganaderia en la Sierra de San Pedro Mártir. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 14–16. Ensenada: CICESE.

———. 1991b. La ganaderia en San Pedro Mártir. In *Memoria de la III semana de la exploración y la historia: Sierra de San Pedro Mártir,* tech. coord. C. Lazcáno-Sahagún, 17–19, Ensenada: Universidad Autónoma de Baja California.

Meling-Pompa, D. 1996. Cattle ranching in Sierra San Pedro Mártir. In *Strategies for Conservation of the Sierra San Pedro Mártir,* ed. E. Franco-Vizcaíno, H. de la Cueva, and C. Montes, 9–10. Ensenada: CICESE.

Mellink-Bijtel, E. 1991. Mamíferos conocidos de la Sierra de San Pedro Mártir. In *Memoria de la III semana de la exploración y la historia: Sierra de San Pedro Mártir,* tech. coord. C. Lazcáno-Sahagún, 45–48. Ensenada: Universidad Autónoma de Baja California.

———. 1993. The president spoke. In *Counting Sheep: Twenty Ways of Seeing Desert Bighorn,* ed. G. Nabhan, 202–20. Tucson: University of Arizona Press.

———. 1996. Potential conservation problems of native mammals in the Sierra San Pedro Mártir. In *Strategies for Conservation of the Sierra San Pedro Mártir,* ed. E. Franco-Vizcaíno, H. de la Cueva, and C. Montes, 14. Ensenada: CICESE.

Mendoza, E., J. Luna, and T. Gómez. 1972. A study of cloudiness in Mexico through meteorolgical satellites. *Boletín del Observatorio Tonantzintla y Tacubaya* 38:215.

Martínez, M. 1947. *Baja California: Reseña histórica del territorio y de su flora.* México, D.F.: Ediciónes Botas.

Mesta, R. 1996. Potential of the Sierra San Pedro Mártir for reintroduction of the California condor. In *Strategies for Conservation of the Sierra San Pedro Mártir,* ed. E. Franco-Vizcaíno, H. de la Cueva, and C. Montes, 13. Ensenada: CICESE.

Miller, D. H. 1955. *Snow Cover and Climate in the Sierra Nevada, California.* University of California Press Publications in Geography II. Berkeley: University of California Press.

Minnich, R. A. 1983. Fire mosaics in southern California and northern Baja California. *Science* 219:1287–94.

———. 1986. Snow levels and amounts in the mountains of southern California. *Journal of Hydrology* 89:37–58.

———. 1987a. The distribution of forest trees in northern Baja California, Mexico. *Madroño* 34:98–127.

———. 1987b. Fire behavior in southern California chaparral before fire control: The Mount Wilson burns at the turn of the century. *Annals of the Association of American Geographers* 77:599–618.

———. 1988. The biogeography of fire in the San Bernardino Mountains of California: A historical study. *University of California Publications in Geography* 28:1–120.

———. 1989. Chaparral fire history in San Diego County and adjacent northern Baja California: An evaluation of natural fire regimes and the effects of suppression management. In *The Chaparral: Paradigms Reexamined,* ed. S. C. Keeley, 37–47. Natural History Museum of Los Angeles County Science Series, Vol. 34. Los Angeles: Natural History Museum.

Minnich, R. A., and C. J. Bahre. 1995. Wildland fire and chaparral succession along the California-Baja California boundary. *International Journal of Wildland Fire* 5:13–24.

Minnich, R. A., M. G. Barbour, J. H. Burk, and R. F. Fernau. 1995. Sixty years of change in Californian conifer forests of the San Bernardino Mountains. *Conservation Biology* 9:902–14.

Minnich, R. A., M. G. Barbour, J. H. Burk, and J. Sosa Ramirez. In press. Californian conifer forests under unmanaged fire regimes in the Sierra San Pedro Mártir, Baja California, Mexico. *Journal of Biogeography.*

Minnich, R. A., and Y. H. Chou. 1997. Wildland firepatch dynamics in the chaparral of southern California and northern Baja California. *International Journal of Wildland Fire* 7:221–48.

Minnich, R. A., and E. Franco-Vizcaíno. In press. *Land of Chamise and Pines: Historical Descriptions of Northern Baja California.* Berkeley: University of California Press.

Minnich, R. A., E. Franco-Vizcaíno, J. Sosa-Ramírez, and Y. H. Chou. 1993. Lightning detection rates and wildland fire in the mountains of northern Baja California, Mexico. *Atmósfera* 6:235–253.

Moran, R. 1977. Plant notes from the Sierra Juárez of Baja California, Mexico. *Phytologia* 35:205–14.

Murphy, R. W. 1983. Paleobiogeography and genetic differentiation of the Baja California herpetofauna. *Occasional Papers of the California Academy of Sciences* 13:1–48.

Myatt, R. G. 1975. Geographic and Ecological Variation in *Quercus chrysolepis* Libm. Ph.D. diss., University of California, Davis.

Nelson, E. W. 1921. Lower California and its natural resources. *Memoirs of the National Academy of Sciences* 16:1–194.

O'Conner, J. E., and C. G. Chase. 1989. Uplift of the Sierra San Pedro Mártir, Baja California, Mexico. *Tectonics* 8:833–44.

Ojeda, L., I. Espejel, and R. Sánchez. 1991. Areas protegidas en la frontera norte y desarollo regional. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 40. Ensenada: CICESE.

Owen, R. C. 1963. The use of plants and non-magical techniques in curing illness among the Paipai, Santa Catarina, Baja California, Mexico. *América Indígena* 23:319–44

Passini, J. F., J. Delgadillo, and M. Salazar. 1989. L'ecosystéme forestier de Basse-Californie: Composition floristique, variables écologiques principales, dynamíque. *Acta Oecologica* 10:275–93.

Reyes-Castillo, P. 1991. La modalidad mexicana en reservas de la biosfera. In *The Potential of the Peninsular Range of the Californias as a Biosphere Reserve,* ed. E. Franco-Vizcaíno and J. Sosa-Ramírez, 3. Ensenada: CICESE.

Reyes-Coca, S., F. Miranda-Reyes, and J. García-López. 1990. *Climatología de la región noroeste de México (Baja California, Baja California Sur, Sonora y Sinaloa).* Parte I: *Precipitación: Series de tiempo del valor total mensual y estadísticas del año climatológico.* CICESE Technical Report CIOFIT9001. Ensenada: CICESE.

Roberts, N. C. 1989. *Baja California Plant Field Guide.* La Jolla: Natural History Publishing Company.

Robinson, J. W. 1975. *Camping and Climbing in Baja.* Glendale: La Siesta Press.

Rodriguez-Meraz, M. 1991. Las aves de la Sierra de San Pedro Mártir, Baja California, México. In *Memoria de la III semana de la exploración y la historia: Sierra de San Pedro Mártir,* tech. coord. C. Lazcáno-Sahagún, 41–45. Ensenada: Universidad Autónoma de Baja California.

Rundel, P. W., D. J. Parsons, and D. T. Gordon. 1988. Montane and subalpine vegetation of the Sierra Nevada and Cascade Ranges. In *Terrestrial Vegetation of California,* 2d. ed., ed. M. G. Barbour and J. Major, 559–600. Sacramento: California Native Plant Society.

Rzedowski, J. 1978. *Vegetacíon de México.* México, D.F.: Editorial Limuse.

Savage, M. 1994. Anthropogenic and natural disturbance and patterns of mortality in a mixed conifer forest in California. *Canadian Journal of Forest Research* 24:1149–59.

Sierra, A. 1996. Communication from Antonio Sierra, Ejido Bramadero's forest consultant. In *Strategies for Conservation of the Sierra San Pedro Mártir,* ed. E. Franco-Vizcaíno, H. de la Cueva, and C. Montes, 10–11. Ensenada: CICESE.

Simpson, G. G. 1964. Species density of North American recent mammals. *Systematic Zoology* 13:57–73.

Tapia, M. 1992. Ten years of weather and observing statistics in the San Pedro Mártir. *Revista Mexicana de Astronomía y Astrofísica* 24:179–86.

Taylor, R. J., and L. A. Plannmuller. 1978. The peninsular effect on species diversity and biogeography of Baja California. *American Naturalist* 112:583–93.

Tiscareño, F., and J. W. Robinson. 1969. *José Joaquín Arrillaga. Diary of his Surveys of the Frontier, 1796.* Los Angeles: Dawson's Book Shop.

Vankat, J. L. 1970. Vegetation Change in the Sequoia National Park, California. Ph.D diss., University of California, Davis.

Vankat, J. L., and J. Major. 1978. Vegetation changes in Sequoia National Park, California. *Journal of Biogeography* 5:377–402.

Vasek, F. C. 1985. Southern California white fir. *Madroño* 32:65–77.

Wiggins, I. L. 1944. Notes on the plants of northern Baja California. *Contributions to the Dudley Herbarium* 3:289–305.

———. 1960. The origins and relationships of the land flora. In The biogeography of Baja California and adjacent seas. Part 3: Terrestrial and fresh-water biotas. *Systematic Zoology* 9:148–165.

———. 1980. *Flora of Baja California.* Stanford: Stanford University Press.

Wilber, S. R., and L. F. Kiff. 1980. The California condor in Baja California, Mexico. *American Birds* 34:856–59.

GENERAL BIBLIOGRAPHY OF THE SIERRA SAN PEDRO MÁRTIR

The following is a general bibliography of research and popular articles specific or pertinent to the Sierra San Pedro Mártir. For detailed bibligraphies of Baja California, see Barrett (1965) and Nelson (1921). Other references are given in "Literature Cited."

Alvarez, M. n.d. *Climatología de la Sierra de San Pedro Mártir.* Instituto de Astronomía, Contribución No. 123. México, D.F.: Universidad Nacional Autónoma de México.

Andres Zárate, D. 1991. A Velazquéz se lo tragó el silencio. In *Memoria de la III semana de la exploración y la historia: Sierra de San Pedro Mártir,* tech. coord. C. Lazcáno-Sahagún, 12–17. Ensenada: Universidad Autónoma de Baja California.

Anthony, A. W. 1895. Birds of San Fernando, Lower California. *Auk* XII:134–43.

Barbour, M. G., W. J. Barry, J. Bendímez, J. H. Burk, J. W. Foster, E. Franco-Vizcaíno, M. P. Hamilton, J. W. Menke, and J. Sosa-Ramírez. 1991. *Progress Report: Comparison of Management of Montane Ecosystems in the Peninsular Range of the Californias for the Period September 1989–May 1991.* CICESE Technical Report CEECT9101. Ensenada: CICESE. (English and Spanish).

Bendímez, M. J. 1992. Los Kiliwa y la reserva de la biosfera en San Pedro Mártir. Reporte al Instituto de Investigaciones Sociales, Universidad Autonóma de Baja California, Mexicali.

Bolton, H. E. 1927. *Fray Juan Crespi, Missionary Explorer on the Pacific Coast, 1769–1774.* Berkeley: University of California Press.

Brandegee, T. S. 1893. Southern extension of the California flora. *Zoe* 4:199–210.

Brown, D. E., and C. H. Lowe. 1980. Biotic communities of the Southwest. Map. USDA Forest Service General Technical Report RM-78, Rocky Mountain Forest and Range Experiment Station, Fort Collins.

Case, T. J., and M. L. Cody, ed. 1983. *Island Biogeography in the Sea of Cortez.* Berkeley: University of California Press.

Chou, Y. H., Minnich, R. A., and Dezzani, R. J. 1993. Do fire sizes differ between southern California and Baja California? *Forest Science* 38:835–44.

Clyde, N. 1975. *El Picacho del Diablo: The Conquest of Lower California's Highest Peak, 1932 and 1937.* Los Angeles: Dawson's Book Shop.

Comision Tecnico-Consultiva para la Determinacion Regional de los Coeficientes de Agostadero (COTECOCA). 1981. Tipos de vegetación en el estado de Baja California. Manuscript maps on file at Secretaría de Agricultura y Recursos Hidráulicos, Ensenada.

Cooper, L. 1925. Exploring Baja California's mountains. *Touring Topics* 17:18.

DuShane, H. 1971. *The Baja California Travels of Charles Russell Orcutt.* Dawson's Book Shop. Los Angeles.

Elliot, D. G. 1903. A list of mammals collected by Edmund Heller in the the San Pedro Mártir and Laguna Hanson Mountains and the accompanying coast regions of Lower California, with descriptions of apparently new species. *Publications of the Field Columbian Museum, Zoological Series* III(12): 199–232.

Emory, W. H. 1857. *Report of United States and Mexican Boundary Survey.* Vols. I and II, 34th Congress, 1st. Session, House of Representatives, Ex. Doc. No. 135, Washington, D.C.

Engstrand, I.H.W. 1981. *Spanish Scientists in the New World: The Eighteenth-Century Expeditions.* Seattle: University of Washington Press.

Epling, C. C., and H. Lewis. 1942. The centers of distribution of the chaparral and coastal sage associations. *American Midland Naturalist* 27:445–62.

Epling, C. C., and W. Robinson. 1940. *Pinus muricata* and *Cupressus forbesii* in Baja California. *Madroño* 5:248–50.

Flores Mata, G., J. Jimenez Lopez, X. Madrigal Sanchez, F. Moncayo Ruiz, and F. Takaki. 1971. Memoria del mapa de tipos de vegetación de la República Mexicana. Secretaría de Recursos Hidráulicos, Subsecretaría de Planeación, Dirección General de Estudios, Dirección de Agrología, SRH, México, D.F.

Gómez Ramírez, J. 1988. Edad y crecimiento de la trucha *Salmo gairdneri nelsoni* (Hubbs), de la Sierra San Pedro Mártir, B.C. México. Tesis Profesional (inédita), Facultad de Ciéncias Marinas, Universidad Autónoma de Baja California, Ensenada.

Grinnell, J. 1926. A critical inspection of the gnatcatchers of the Californias. *Proceedings of the California Academy of Sciences* 15:493–500.

———. 1927. New birds from Lower California. *Condor* 29:124–126.

Haiman, R. L. 1973. The Biological Environment and its Modification by Man in the Sierra de Juárez, Baja California. Ph.D. diss., University of California, Los Angeles.

Hawksworth, F. G., P. C. Lightle, and R. F. Scharpf. 1968. *Arceuthobium* in Baja California, Mexico. *The Southwestern Naturalist* 13: 101–2.

Heald, W. F. 1957. Sierra San Pedro Mártir to Baja California's rooftop. *Pacific Discovery* 10:4–9.

Hernandez S., M. A., A. Mancera Orozco, F. Martínez Gonzales, R. Salina Quinard, J. Becerra Martínez, and D. Zavala Zavala. 1977. Observaciones ecológicas fitosanitarias (plagas y enfermedades) y sobre aprovechamientos industriales en las Sierras de Juárez y San Pedro Mártir, en el Estado de Baja California Norte. *Ciéncias Forestales* 2: 3–38.

Hodge, F. W. 1959. *Handbook of American Indians North of Mexico.* 2 vols. New York: Pageant Books.

Huey, L. M. 1927. A discussion of the zonal status of the Sierra San Pedro Mártir, Lower California Mexico, with descriptions of a new kangaroo rat and a new woodpecker from that region. *Transactions of the San Diego Society of Natural History* 5:1–10.

———. 1930. The magic of the pinyons. *Nature Magazine* 33:445–57.

———. 1964. The mammals of Baja California, Mexico. *Transactions of the San Diego Society of Natural History* 13:65–85.

Jaeger, E. C. 1956. The rarest pinyon. *Desert Magazine* 19:10–11.

Kasbeer, T. 1971. Flora of Baja Norte. Glendale, Calif.: La Siesta Press.

La Motte, R. S. 1937. Ecological comparison of Morena Watershed, California, with the Sierra San Pedro Mártir, Mexico. California Forest and Range Experiment Station. (Manuscript on file at Water Resources Center Archives, University of California, Berkeley).

Laylander, D. P. 1987. Sources and strategies for the prehistory of Baja California. Master's thesis. San Diego State University.

Lazcáno-Sahagún C. 1991. El descubrimiento de la Sierra de San Pedro Mártir. In *Memoria de la III semana de la exploración y la historia: Sierra de San Pedro Mártir,* tech. coord. C. Lazcáno-Sahagún, 9–12. Ensenada: Universidad Autónoma de Baja California.

Lindsay, G. E. 1983. History of scientific exploration in the Sea of Cortéz. In *Island Biogeography in the Sea of Cortez,* ed. T. J. Case and M. L. Cody, 3–12 Berkeley: University of California Press.

Lindsay, S. L. 1981. Taxonomic and bigeographic relationship of Baja California chickarees (*Tamiasciurus*). *Journal of Mammology* 62: 673–82.

Linsdale, J. M. 1932. Amphibians and reptiles from Lower California. *University of California Publications in Zoology* 38:345–86.

Lowe, C. H., and D. E. Brown. 1982. Introduction. *Biotic Communities of the American Southwest—United States and Mexico,* ed. D. B. Brown. *Desert Plants* 4:1–341.

Martínez, M. 1953. *Las pinaceas mexicanas.* 2d. ed. México, D.F.: Universidad Nacional Autónoma de México.

Minnich, R. A. 1982. *Pseudotsuga macrocarpa* in Baja California? *Madroño* 29:22–31.

———. 1986. Range extensions and corrections for *Pinus jeffreyi* and *P. coulteri* (Pinaceae) in northern Baja California. *Madroño* 33:144–46.

Minnich, R. A., and R. J. Dezzani. 1991. Fire and vegetation management in urbanized chaparral watersheds. In *California Watersheds at the Urban Interface: Proceedings of the Third Biennial Watershed Conference,* 67–84. University of California Water Resources Center Report No. 75. Davis: University of California.

Mixco, M. J. 1983. *When I Have Donned My Crest of Stars.* University of Utah Anthropological Papers No. 107. Salt Lake City: University of Utah Press.

———. 1985. *Kiliwa Dictionary.* University of Utah Anthropological Papers No. 109. Salt Lake City: University of Utah Press.

Mooney, H., and A. Harrison. 1972. The vegetational gradient on the lower slopes of the Sierra San Pedro Mártir in northwest Baja California. *Madroño* 21:439–45.

Moran, R. 1977. Botany of the San Pedro Mártir trip. Manuscript. San Diego Museum of Natural History.

Muller, C. H. 1967. Relictual origins of insular endemics in *Quercus.* In *Proceedings of the Symposium on the Biology of the California Islands,* ed. R. N. Philbrick, 73–77. Santa Barbara: Santa Barbara Botanic Garden.

North, A. W. 1907a. Hunting the bighorn. *Sunset Magazine* Oct.: 523–32.

———. 1907b. The uncharted Sierra of the San Pedro Mártir. *American Geographical Society Bulletin* 39:544–54.

———. 1910. *Camp and Camino in Lower California.* New York: Baker and Taylor.

Orcutt, C. R. 1886a. Northern Lower California. *The West American Scientist* 2:37–41.

———. 1886b. A botanical trip. *The West American Scientist* 2:54–58.

———. 1887. The oaks of southern and Baja California. *West American Scientist* 3:135–39.

———. 1892. The forests of Lower California. *Garden and Forest* 5: 183–87

Patterson, D., and J. A. Powell. 1959. Lepidoptera collecting in the Sierra San Pedro Mártir, Baja California. *Journal of the Lepidopterist's Society* 13:229–35.

Peinado, M., F. Alcaraz, J. L. Aguirre, and J. Delgadillo. 1995a. Major plant communities of warm North American deserts. *Journal of Vegetation Science* 6:79–94.

Peinado, M., F. Alcaraz, J. L. Aguirre, J. Delgadillo, and I. Aguado. 1995b. Shrubland formations and associations in Mediterranean-desert transitional zones of northwestern Baja California. *Vegetation* 117:165–79.

Peinado, M., C. Bartolome, J. Delgadillo, and I. Aguado. 1994. Pisos de vegetación de la Sierra de San Pedro Mártir, Baja California, Mexico. *Acta Botánica* 29:1–30.

Reyes, S., F. Miranda, and P. Daget. 1988. Interannual variability of the rainfall field over Baja California: Middle-latitude versus tropical influences. In *Proceedings, 5th. International Conference on Mediterranean Ecosystems,* ed. F. diCastri, C. Floret, S. Rambal, and J. Roy, 373–80. Paris: International Union of Biological Sciences.

Reyes-Coca, S., and P. R. Salazar. 1985. Variabilidad de la precipitación en la Peninsula de Baja California. *Revista Geofísica* 22/23:111–28.

Ruiz-Campos G. 1989. Repoblación natural por trucha arcoíris (*Salmo gairdneri nelsoni*) en un transecto del Arroyo San Rafael, noroeste de la Sierra San Pedro Mártir, Baja California, Mexico. *Southwestern Naturalist* 34:552–56.

Ruiz-Campos G., and P. Cota-Serrano. 1992. Diet of the rainbow trout (*Oncorhynchus mykiss nelsoni*) from the Arroyo San Rafael, Sierra San Pedro Mártir, Baja California, Mexico. *Southwestern Naturalist* 37:166–77.

Ruiz-Campos, G., E. P. Pister, and G. A. Compean-Jimenez. 1997. Age and growth of Nelson's trout, *Oncorhynchus mykiss nelsoni*, from Arroyo San Rafael, Sierra San Pedro Mártir, Baja California, Mexico. *Southwestern Naturalist* 42:74–85.

Servín, Manuel P. 1968. *The Apostolic Life of Fernando Consag: Explorer of Lower California*. Los Angeles: Dawson's Book Shop.

Shreve, F. 1936. The transition from desert to chaparral in Baja California. *Madroño* 3:257–64.

Simpson, L. B. 1938. *California in 1792. The Expedition of José Longinos Martínez*. San Marino: The Huntington Library.

———. 1961. *Journal of José Longinos Martínez: Notes and Observations of the Naturalist of the Botanical Expedition in Old and New California and the South Coast, 1791–1792*. San Francisco: John Howell Books.

Smith, D. E., and F. J. Teggart. 1909. *Diary of Gaspar de Portóla during the California Expedition of 1769–70*. Publications of the Academy of Pacific Coast History Vol. 1. No. 3. Berkeley: University of California.

Sosa-Ramírez, J., and E. Franco-Vizcaíno. 1991. *Comparison of the Effects of Management in Two Montane Ecosystems in the Peninsular Range of the Californias: Evaluation of the Feasibility of a Transborder Biosphere Reserve*. CICESE Technical Report CIEC59101. Ensenada: CICESE. (English and Spanish).

Standley, P. C. 1920–26. Trees and shrubs of Mexico. *Contributions from the National Herbarium* 23:1–1721.

Tibesar, A. 1955. *Writings of Junipero Serra*. 4 vols. Washington, D.C.: Academy of American Franciscan History.

Townsend, C. M. 1923. Birds collected in Lower California. *Bulletin of the American Museum of Natural History* 48:1–26.

Wells, P. V. 1968. New taxa, combinations and chromosome numbers in *Arctostaphylos* (Ericaceae). *Madroño* 19:193–224.

Welsh, H. H. 1988. An ecogeographic analysis of the herpetofauna of the Sierra San Pedro Mártir region, Baja California: With a contribution to the biogeography of the Baja California herpetofauna. *Proceedings of the California Acadedmy of Sciences* 46:1–72.

Werner, L. T. 1957. Fire sweeps El Picacho del Diablo. *Desert Magazine* 20:27–28.

Wiggins, I. L. 1933. New Plants from Baja California. *Contributions to the Dudley Herbarium* 1:161–87.

———. 1944. Collecting ferns in northwestern Mexico. *American Fern Journal* 34:37–49.

———. 1950. Yellow pines and other conifers observed in Lower California. *Journal of the New York Botanical Garden* 41:267–69.

———. 1963. Botanical explorations in Baja California, Mexico. *Plant Science Bulletin* 9:1–6.

Wilber, S. R. 1987. *The Birds of Baja California*. Berkeley: University of California Press.

Wolf, C. B. 1948. Taxonomic and distributional studies of the New World cypresses. *Aliso* 1:1–250.

Woodford, A. O., and T. R. Harris. 1938. Geological reconnassaince across Sierra San Pedro Mártir, Baja California. *Bulletin of the Geological Society of America* 49:1297–1335.